Journal of

American Society of Range Management

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Cover Photo—Applied Landscape Management in Pinyon-Juniper Control, Carson National Forest.

See Article by Robert M. Williamson and W. F. Currier, page 2.

Applied Landscape Management in Plant Control[1]

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Highlight

Plant control results in drastic abrupt changes in the dominating landscape of a site. To lessen this impact and create a pleasing aspect, the land manager must use his ingenuity in applying techniques that will result in coordinating basic data, soils, wildlife needs, esthetics, and range to arrive at an action plan that will maximize all resources and activities. Perhaps the most difficult land resource value to assess, maintain, and manage, is natural beauty. Thus, the application of a plant control project is a challenge in landscape management application. Experience has shown that, through a joint effort by all disciplines, it is possible to apply a practical form of landscape management that results in the retention and even enhancement of the natural beauty while accomplishing the basic resource objectives desired in a plant control program.

Grazing by domestic livestock in the Southwest dates back to its introduction by the Spanish in the 1600's. By the beginning of the twentieth century, low value forage plants—pinyon, juniper, mesquite, chaparral, and in some cases pine, began to invade natural grasslands. The invasion progressed very rapidly.

At present, there are 2,500,000 acres of formerly open grasslands that have converted to low value forage plants in the Southwestern Region of the Forest Service. This change in vegetation has resulted in deterioration, loss of forage production, inferior wildlife habitat for certain species, and a change in the hydrologic water balance in affected sites.

Accelerated invasion by woody plant species has now progressed to the point where mechanical or chemical treatment must be applied. Control by these methods results in dramatic changes in the landscape. Now that there is so much concern by so many people about the environment, the land manager, particularly the public land manager, must place high priority on developing techniques and procedures which make environmental change acceptable to the public. Plant control treatments must be esthetically pleasing. The natural beauty of the landscape cannot be marred. Landscape management has become another of many responsibilities of the land manager, to be fitted into all plant control projects along with range, watershed, and wildlife considerations.

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Project Planning and Objectives

The first step in accomplishing a plant control project is assembling basic resource data. Range analysis, soil classification maps, wildlife habitat inventories, sediment studies, and other hydrologic data should be considered. These collectively determine the sites where plant control can be applied to provide overall benefit. Through joint effort with the landscape architect and other specialists, it is possible to blend this basic resource data with the concepts of wild land landscape management. This develops an overall plan that will fulfill all of the multiple use management objectives. Experience shows that the quality of the end product is directly related to the quality of the planning effort. A sound plan cannot be built on assumptions. It must be based on facts and proved theory.

The Ranger District Multiple Use Plan sets the coordination requirements and management decisions that apply to the management unit in which the control work is to be carried out. Soil scientists provide soils information. The wildlife biologists can point out key areas and predict what the effects of plant control will be on wildlife. Watershed specialists can tell what work is necessary to reduce soil loss and improve the hydrologic condition. The range manager can evaluate the existing situation, plan the necessary livestock controls during the action program, and define the management procedures necessary to maintain the site once a grassland type is restored. The landscape architect should provide the artistic perception to insure the natural appearance of the finished project. This last mentioned skill has not always been considered as necessary in plant control project planning. As a result, we have many horrible examples which continue to haunt us and are hindering the overall program because of adverse public opinion (Fig. 1). Natural beauty must be a primary objective in plant control project planning and must be considered in all aspects of multiple use management of wild lands. Landscape management in plant control activities becomes the application of many variables to a procedure that results in a completed project that enhances all multiple use values (Fig. 2).

Soils

A detailed soil survey will identify the soils with forage production potential and the areas that should not be treated. Where soils are highly variable, adhering to soil information will often produce ideal patterns. Where soils are homogeneous, large, open patterns could develop if all treatable soils are worked without considering other on-site values.

Wildlife

Wildlife habitat needs frequently are very critical in areas where plant control is being considered.

FIG. 1. Layout on this plant control area was not coordinated with soils, wildlife needs and esthetics to arrive at a pattern that would maximize all resources and activities present.

This is especially true in the pinyon-juniper type of the Southwest. Cover, as well as food supplies must be considered. Where large expanses are worked without concern for wildlife cover, much acreage is lost from a wildlife point of view even though overall wildlife forage is improved. If cover is left at irregular intervals, not greater than ¼ to ½ mile apart and edges undulated, acreage can be added to the wildlife habitat. Small game and songbird species should not be neglected when prescribing plant control, although they often are. Scattered brush piles—one per acre or less—or individual tree carcasses will often meet the needs of these species and improve their habitat while not detracting from the esthetic value. Large, randomly spaced trees scattered throughout the project will aid in providing spring forbs and grasses which are extremely important to wildlife habitat in the Southwest (Fig. 3). At the same time, these trees provide a pleasing aspect to the landscape.

Watershed

Much plant control work is undertaken to increase water production. One study in the chaparral type in Arizona has indicated about 3.0 inches more water per year as a result of brush control. (Pase and Ingebo, 1965). Increased water loses much of its value if the quality has deteriorated as a result of soil mismanagement. On some sites, removal of the over-story and exposure of the soil surface becomes a catastrophe from a soil stability point of view. These untreatable areas can be used effectively in arriving at the final esthetic patterns. The opposite may also be true. By removing low value woody species and establishing a grass cover, active erosion can be arrested and soil stability developed. Gullies and polluted water detract from the esthetic values of the land.

Range

In range management the objective of a plant control project is to develop the range resource to its maximum, consistent with other Multiple Use values.

To blend these values, a range environmental analysis must be available. The analysis provides areas of high priority for plant control and the plant species requiring control for range management purposes, and location for potential structural improvements, fences, and water developments that will be needed for management of livestock during and after the control program.

Most plant control projects are carried out on areas where livestock are presently grazing. This makes the development of a feasible, overall range management plan necessary before beginning a

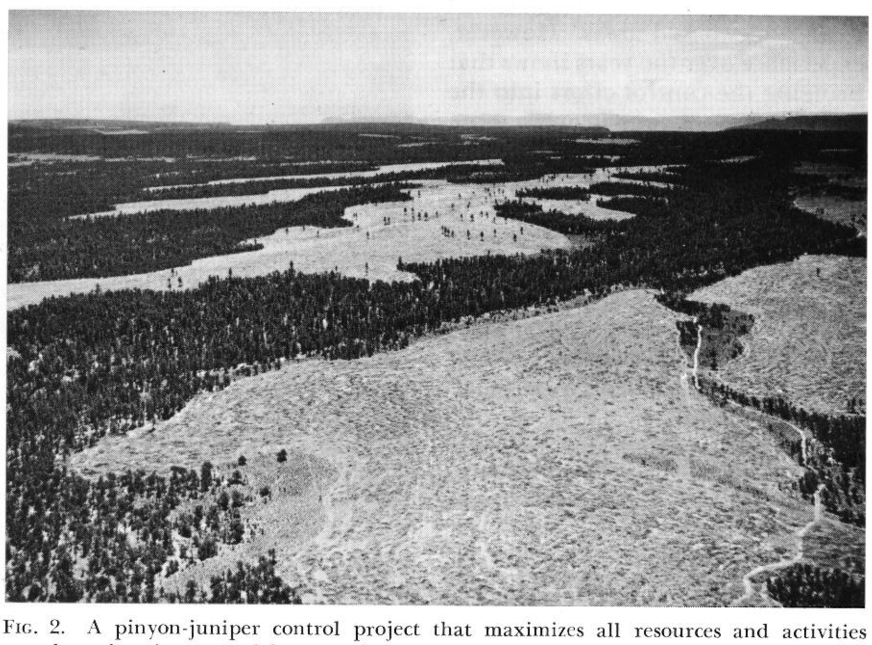

FIG. 2. A pinyon-juniper control project that maximizes all resources and activities and retains the natural beauty of the landscape.

FIG. 3. Shows large randomly spaced trees left to provide spring forbs and grasses and depict a pleasing aspect to a landscape where pinyon-juniper control has been accomplished.

plant control project. The analysis and management plan becomes the basic range data to use in coordinating and planning a plant control program.

Natural Beauty

Until recently, natural beauty was not a major consideration. An example of this is in the plant control work in travel influence zones.[2] Earlier plant control efforts left buffer strips for screening between roads and worked areas. However, experience over the years shows that bringing the control effort into the travel influence zone is much more pleasing than leaving a buffer zone along roads. By having this arbitrary leave area, a false impression is left to the casual viewer, and draws attention to the control area. Many times when control work is brought into the travel influence zone, the casual viewer will not be aware of the vegetative change.

In this day of air travel, the pattern as presented from an aerial view must also be considered. A considerable acreage is seen and observed by more people from the air than is ever seen via the ground route. Viewed from the air, straight edges and rectangular clearings are examples of objectionable patterns. However, if other guidelines are followed, the aerial view will be pleasing to the eye.

Existing vegetative distribution provides evidence of natural openings that once were present. Many times this existing pattern will coincide with the desirable pattern.

Where other factors do not create undulation in edges, it should be done artificially. Land patterns, in areas of varied ownership, must be supervised to hold straight lines to a minimum. Many times it will be necessary to coordinate new work with old work done under different standards.

Feathering can be accomplished in layout by taking advantage of various stand densities, or it can be created artificially. Feathering is perhaps one of the hardest practices to apply in pattern layout.

When applying these practices, it is very important to continually be aware of the dimensional aspects that are inherent in plant control work. Finished projects are viewed from all angles and should present the desired characteristics from any direction. A well broken up pattern from one view can become a wide open expanse from another angle, thus detracting from the natural beauty.

We have dwelled at length on the layout aspects of plant control as this is what determines success in a

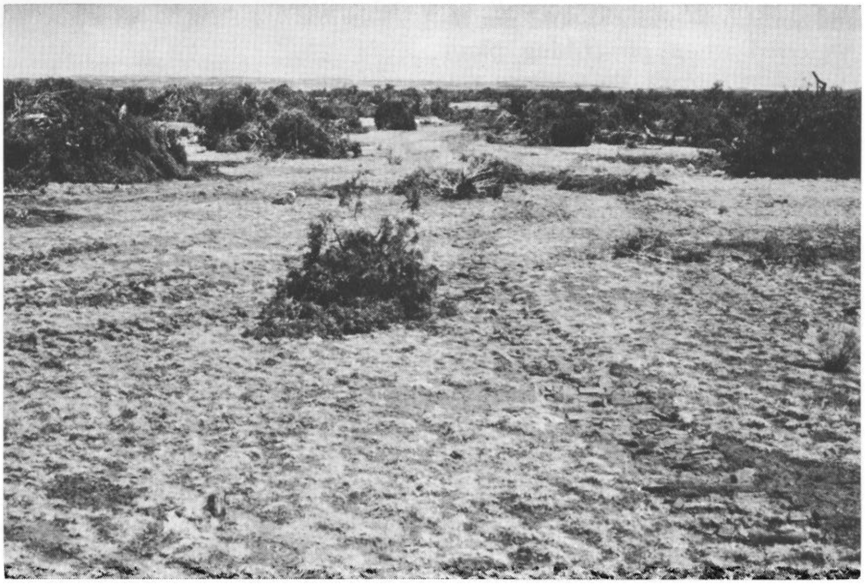

FIG. 4. A pinyon-juniper control area where esthetic values were not considered. Cleanup will increase available forage and improve esthetic.

[2] Travel Influence Zones are defined as areas in which beauty of the landscape and other esthetic values are an important part of the outdoor environment. These offer significant opportunities for existing, planned, or anticipated recreational use and enjoyment by people visiting or traveling through the zone.

FIG. 5. Completed pinyon-juniper project where feathering technique has added to the edge effect. Grass establishment is a result of seeding in conjunction with control effort.

project from a landscape point of view. Cleanup of debris often provides the finishing touches. Failure to clean up often results in criticism and adverse publicity for an otherwise successful project (Fig. 4). There are many methods of control, with no one best method that can be applied to all projects. It is important to consider cleanup requirements in initial control method planning. Frequently, cleanup restrictions will dictate the control method.

A pinyon-juniper control project is an example of how cleanup is structured into the overall project effort. Control of pinyon-juniper can be accomplished by pushing. Through development of a burning plan, fire can be used to remove the tree carcasses. (Southwest Interagency Fire Council, 1968).

By using a helicopter, broadcast seeding can be accomplished. To prepare the seedbed, cover the seed, and smooth up the rough edges left from the burning, an anchor chain can be dragged over the area (Fig. 5). The results will be an esthetically pleasing project that meets the overall objectives. In some cases, trees are piled or windrowed prior to burning to insure a greater consumption of debris.

When using fire in the cleanup sequence, it is extremely important to time burning so that air pollution is held to a minimum. Many times other means of disposal will have to be used to prevent air pollution.

Control and cleanup can be done in one operation with the "tree crusher" (Fig. 6). Such a machine uproots and crushes the trees in one operation. This control method has been extremely successful in dense, rock-free mature pinyon-juniper stands and especially where air pollution can be a factor.

Each species requires different approaches to the cleanup task. Each stand or site can also require a different approach. The important thing is to accomplish cleanup to a degree that is pleasing to the eye. Complete cleanup could result in a conflict with the determined needs of a basic resource. When this occurs, a coordinated level must be reached that will minimize all aspects of the cleanup phase.

The importance of keeping the public informed about plant control projects can't be forgotten. This can be done through a well planned and coordinated public information program. Of utmost importance in this approach is presenting the objectives clearly, describing the intermediate steps, the time element involved, and how the finished project will fit into the total environment.

FIG. 6. Tree crusher in action—control and cleanup is accomplished in one operation. Readily available fuel wood is a side benefit of this technique.

Summary

Most of the factors involved in a successful multiple use plant control project have been discussed. How are these meshed together into a simple set of clear-cut guidelines that will guarantee the desired results in all situations? Experience shows that this is not possible. Each and every site has its own characteristics and must be treated individually.

How then are guidelines for individual projects prepared? First, a multiple use survey and report is developed. This gives the line officer insight into the plant control proposal and evaluates the effects that alternatives of location, design and standards will have on existing and potential resources and activities. It goes on to accurately define the coordination opportunities to be included in the action plan to enhance beneficial and minimize adverse aspects of the proposal. Once this is accomplished, guidelines can be developed that achieve the desired coordination.

Plant control itself will alter the ecosystem that is currently on the site. The land manager must be in a position to insert offsetting influences if he is to retain accomplishments. These influences can and should be built into the management practices applied to the area following plant control.

Plant control projects go on after the initial on-the-ground work is done. There must be management and followup maintenance to insure that benefits are retained. All too often interest lessens with the completion of the plant control sequence. When management has not been pre-planned and related development work, waters, and fences programmed and accomplished simultaneously with plant control, the users cannot take the full advantage of the benefits, nor does the administrator fulfill his obligations.

A project is complete and successful only when a management plan is activated and followup action assured, resulting in the perpetuation of the acquired benefits. The critical factor of overall planning cannot be neglected if landscape management in plant control projects is to be successful.

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Grazing History of the Northwest[1]

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Highlight

The earliest grazing in the Northwest (which probably began about 1700) was by Indian horses. Livestock—a few head of cattle—were first brought to the Northwest at Nootka Bay on Vancouver Island, B.C., by Spaniards in 1789. By 1825, there were 27 head of cattle at Vancouver, Wash., near the mouth of the Columbia River. Marcus Whitman brought cattle to the area east of the Cascade Mountains in 1836. Mass movements of cattle took place from western Oregon to east of the Cascades during the 1860's. Numbers skyrocketed which resulted in sizeable exportations of livestock in the late 1800's to regions east of the Rocky Mountains, largely for building base herds. These drives contributed significantly to development of the livestock industry east of the Rockies, although they have been largely neglected by writers who chose, rather, to popularize the cattle drives from Texas and the Southwest.

Raising livestock on rangeland is still, and will continue to be, one of the major basic industries in the Pacific Northwest. There are many millions of acres of private and public rangeland and grazable woodland in the Pacific Northwest on which concurrent grazing by livestock and game should continue to be one of the major uses of the resource.

The history of grazing seems to have followed a similar pattern throughout the world. First, an abundance of native forage—one of the greatest natural resources available to man—then deterioration or loss of that resource, followed by efforts for rehabilitation. This paper summarizes the grazing history of Oregon, Washington, and British Columbia. The history of grazing in this region is a very large part of the history of the people who developed the region.

In 1805 when Lewis and Clark reached the mouth of the Columbia River, completing their journey of exploration, the Northwest was a vast land untouched and unexploited by civilization. The natural resources were mainly timber, minerals, water, and land. But before any of these could be developed and made to serve mankind, people had to be able to live from the land. An all-important resource, namely grass, made this possible. Here was a resource immediately necessary and immediately available.

In the early history of the Northwest, cattle supplied several basic needs of people. Beef and milk were basic foods. Cattle also supplied fat and cheese. They were used as draft animals to supply power for plowing, to pull wagons and other implements; and hides provided leather for many purposes. People even made use of cattle hoofs and horns. Cattle,

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FIG. 1. The bunchgrass range of the Pacific Northwest. (Soil Conservation Service photo)

sheep, and horses all depended upon grass for their sustenance.

In the early 1800's, this vast region produced some of the finest grassland in the world (Fig. 1). Component species collectively were called bunchgrass. Three major species were prominent in this vast sea of grass which lay east of the Cascade Mountains. These are bluebunch wheatgrass (*Agropyron spicatum* Pursh.), Idaho fescue (*Festuca idahoensis* Elmer.) and Sandberg bluegrass (*Poa secunda* Presl.). The larger grasses grew 18 to 36 inches tall and, either green or dry, were excellent forage for livestock. In the valleys, on the hills and on the plains, these grasses extended like endless seas. Along with this seemingly unlimited supply of food for livestock was also an abundance of water. Much of the water was poorly distributed, but over-all, few places in the world had ever been endowed so lavishly with this essential resource.

Indians were making some use of the grass. In a Shoshone village, Lewis and Clark saw 700 horses. They estimated that there were thousands more in the hills. These were descendants of Spanish horses from the Southwest. It is believed that the Shoshone Indians acquired their first horses between 1690 and 1700 from a Spanish mission at Santa Fe, N. Mexico (Haines, 1938). By 1730, horses probably ranged in the Snake River Valley of southern Idaho and throughout parts of eastern Oregon and Washington. When the first white men came, these horses along with game, mostly deer and elk, were the only consumers of native foreage. Very few buffalo moved into the Pacific Northwest region. A few sometimes entered the Snake River Valley, and some may have moved as far west as Wenatchee, Wash.; but they were never a factor in grass consumption in the Northwest.

Probably unknown to Lewis and Clark when they reached the Pacific Ocean in 1805, was the fact that 16 years before (in 1789) the Spaniards had brought a few head of cattle to their settlement at Nootka Bay on Vancouver Island, B.C., some 400 miles to the north. These cattle had been brought by sailing vessel from the Hawaiian Islands. In 1792, three or four head of cattle were moved across the strait to Neah Bay, Washington. These were the first known cattle in the Northwest.

By 1825 cattle were beginning to be a factor in the economic life of certain isolated areas. By that time, there were 27 head at Vancouver near the mouth of the Columbia River. The following year in what is now eastern Washington there were a few cattle in Okanogan Valley and 3 young cows at Fort Colville.

Marcus Whitman brought several head of cattle across the country to Walla Walla Valley, Washington, in 1836. By this time people in the little settlements throughout the Northwest were recognizing the importance of cattle and sheep and that there was food in abundance for such livestock. The first recorded kill of cattle specifically for beef was at Vancouver, Washington, in 1836. Up to this time, cattle were kept to produce milk and cheese and to increase in numbers.

By the middle 1830's, Oregon Territory was being recognized as a land of opportunity. More and more the word was being spread throughout the East that here was a land from the west slope of the Rockies to the Pacific Ocean where grass was never ending, where water was in abundance, and where timber was available for cabins and other buildings, all free to men with the courage to take it. Moreover, it was accepted as a fact that the climate was such that livestock could live on the open range throughout the winter and thrive. Even in the face of early experiences to the contrary, this theory was believed, a theory which was to prove disastrous in the years ahead. Newspapers in eastern towns and cities published glowing accounts of this region. It was a land where men and their families had only to reach to become economically free and independent.

Consequently, people came—immigrants, soldiers, missionaries, and fortune seekers.

In 1835, President Jackson sent

William A. Slacum on a mission of inquiry into Oregon Territory. Mr. Slacum considered the Willamette Valley of Oregon the finest grazing country in the world. He assisted in transporting men from the Willamette Valley by ship to California to purchase and drive a herd of cattle back to Oregon. This was in January 1837. Late that summer the men returned with nearly 800 head of cattle.

Two years later a committee of the Hudsons Bay Company established the Puget Sound Agricultural Company. It established extensive farms at Nisqually and Cowlitz in western Washington and imported cattle and sheep from California. The objective of the Company was to develop flocks and herds on an extensive scale to produce wool, hides, and tallow for the British market.

By 1850, from small beginnings, herds were expanding throughout the Territory. Thousands of cattle were being driven across the plains to the Northwest. This region was on the eve of one of the most colorful, courageous, and finally, disappointing periods in American history. The day of the cattle king and the range baron, the day of exploitation of rangeland had arrived.

In 1860 there were 65,000 people in the new state of Oregon and the territory of Washington and nearly 200,000 cattle. Expansion in the use of rangeland had been fantastic.

Along with the growth of the cattle industry was the expansion of sheep raising. The Puget Sound Agricultural Company raised sheep on its Nisqually and Cowlitz farms. A few head were brought to the mission at Waiilatpu near Walla Walla, Washington, in 1841 from Hawaiian Islands. A flock of sheep was driven to the Willamette Valley in the wake of that first cattle drive from California in 1837. In 1844, the first sheep crossed the plains into Oregon.

Emphasis usually is placed on cattle and sheep as the consumers and destroyers of grass, but it must be remembered that horses also increased in great numbers. Everyone needed horses. In addition to those raised and used, there were thousands of wild horses on the range. This explosive expansion of livestock on the open range was soon to take its toll, but up to this time it was barely noticeable.

The oldtime cattleman, the rangeland operator of 1850–1890, was probably the toughest, most courageous, most independent, sometimes the kindest, and often the ornriest character this country ever produced. From where we are now, he appears to have been in some respects a man of vision and in others a man without foresight. The normal risks he accepted as part of his business would appear overwhelming to most people today. Let's look at some of the facts of life that faced him. First, he had to acquire a few head of cattle and get them to the open range. Then his troubles really began. To name a few, there were marauding Indians; rustlers (other men trying this method of getting a start for themselves); natural predators such as coyotes, wolves and cougars; poison weeds and roots which cattle often ate; rattlesnakes; natural disease; grass and forest fires; and bitter cold winters. These things the cattleman accepted, fought, and finally overcame. His real fight for existence was yet to come.

Despite these hazards, the cattle industry boomed. These were the days when the cattleman was king, the day of the cattle drive, the cow town and the cowboy—a colorful and interesting period.

Even in 1850, cattlemen were striving to improve the quality of their livestock. Purebred cattle, sheep, and horses were brought to the region.

Until about 1870, all the products of the expanding cattle and sheep industry were utilized locally. Mining operations were extensive and thousands of miners throughout the Northwest required meat and other products. The booming Cariboo district in British Columbia was one of the most notable markets for livestock. Soon after the discovery of gold in this region, miners came by the shipload from California to Victoria, then moved inland to the gold fields. In the summer of 1858, General Joel Palmer organized a cattle drive at Fort Okanogan in Washington Territory. This drive moved up the Okanogan River, across into British Columbia south of Osoyoos, and then to the vicinity of Kamloops, where the miners happily welcomed the General and his herd.

Later, one of the great cattle kings of the Northwest, Ben Snipes, drove herds from the Yakima Valley to the Cariboo mining area. Some cattle were even driven from Oregon to this lucrative market. Local men in British Columbia soon recognized the possibility of raising cattle for this market on their own rangelands and, thus, the cattle industry in British Columbia was born.

The contribution of the Northwest to the early expanding cattle business of the Great Plains has been given scant notice. Cattle drives from Texas and the Southwest have been highly popularized by writers whereas the role of the Northwest, although prominent, has been neglected. It is important to the history of the great American West to recognize the contribution made by the cattle industry of the Pacific Northwest.

During the 1840's and 1850's, cattle multiplied rapidly in the Pacific Northwest, particularly in western Oregon. With the increase of mining in eastern British Columbia, Washington, and Oregon during 1858, a rush of people moved eastward and soon the Columbia Basin was swarming with people. This created a huge demand for food. To satisfy this demand, cattlemen began moving their herds from western Oregon into the Columbia Basin during the 1860's and even later. So rapid was this expansion that by the early 1870's cattlemen of the Pacific Northwest were facing a depression because their markets were glutted. At the beginning of 1872 the average price in Oregon for oxen and other cattle was $23.23 per head. In January 1877 it was $11.80. Prices remained low until 1880 when there was a slight increase which continued for about 5 years. This depressed price in Oregon was similar to that for the United States during the late 1870's.

Relief came to these hard-pressed cattlemen from increasing contacts made with markets east of the Rocky Mountains where there was a growing demand for cattle (Oliphant, 1946). In 1875 it was reported that hundreds of cattle were bought at Walla Walla, Washington, and driven to the Wyoming Territory. This started a slight movement of cattle eastward from the Northwest. Year by year this movement increased after an effective beginning in 1876. One buyer's herd in 1877 reportedly numbered 16,000 head and there were other cattle buyers moving cattle eastward each year. Because of their quality, a large proportion of these cattle was being used to build base herds east of the Rocky Mountains.

The movement of cattle eastward from Oregon country reached its peak in 1880. It was estimated that about 200,000 head had moved eastward from the Pacific Northwest that year. The winter of 1880–81 decimated herds throughout the Northwest but numbers built up again so that in 1882 a large number of livestock, including sheep and horses, were trailed eastward. The drive in 1882 was the last important one to be made from Oregon country because the great surplus of cattle had been moved out of this region. With the completion of the Northern Pacific Railroad in 1883, trailing livestock out of the far Northwest diminished and shipping by rail increased. A rail shipment of Oregon cattle was made from Winnemucca, Nev., to Chicago as early as 1878, and in 1879 shipments to feeding grounds in Nebraska and Iowa were recorded. By 1885, the Utah and Northern Railroad and the Oregon Short Line also were providing a market outlet.

It is noteworthy that the cattle from the Northwest were considered by the Wyoming buyers to be superior to Texas cattle as a base upon which to build their herds. Before 1876 or 1878 the great bulk of cattle were brought to that area from Texas. After that, their cattle came from the Northwest, Nevada, Utah, and Idaho until it was reported that they had "practically exhausted the supply of Nevada, Oregon and Washington Territory."

During this period of grazing on the open range, there was no such thing as ownership of land, except that the Indians actually owned all of it. It is true that cattle and sheep men often established a place as their general headquarters or home range, but livestock grazed without much control. A large cattle owner might consider that a certain general area, extending perhaps 50 to 100 miles or even more from his home range, was his range although he had no legal claim to the land. Under this method of management, cattle from two or more owners often mingled on the same range. A method of branding and marking the calves was established, but often a cattleman did not know, even at roundup time, how many cattle were actually his.

Carlson (1940) reported that in 1865, a Mr. F. Fry, an early eastern Washington settler, said "The most of which (eastern Washington) is spread over with rich succulent grass, forming one of those grand natural pastures, whereon innumerable herds of cattle might be raised with very little attention, the climate being so mild as to allow their running at large during the winter—the grass matures in the early part of the season and cures while standing on the ground, making winter as well as summer pasture—no part of America is better adapted to the growing of wool and sheep."

Mr. Fry certainly was correct about the grand and natural pasture. His statement about the need for little attention to the livestock was generally accepted throughout the region. One newspaper of that time stated that a steer worth $5 at birth was worth $45 after four or five years on the open range. This was sometimes true provided of course the steer was still around at the end of 4 or 5 years.

One of the hazards that caught up with the stockmen several times from 1850 to 1890 was the climate, which was anything but mild. It was commonly believed that there was no need to raise hay and store it for winter use because winters in the Northwest were such that livestock could take care of themselves out in the open. Dry grass was available under the snow or sticking through it; temperatures were such that animals could live through winter in comparative comfort.

Despite the warnings of the winter of 1847–48, cattlemen believed in the yearlong open-range idea, and they were fairly correct until the winter of 1861–62. Snow came early, it piled deep, temperatures fell to more than 30 degrees below zero in nearly all areas east of the Cascades. It stayed that way for weeks. Later a warm spell was followed by more subzero weather which caused a crust on the snow so hard that no animal could break through to find feed. Through starvation and exposure to subzero temperatures, cattle and sheep died by the thousands. Some large owners were wiped out completely. The range was a graveyard in the spring of 1862. A Walla Walla newspaper stated that a thousand yards from town, one could almost step from one dead cow to another throughout the whole valley.

This was a catastrophe for stockmen, an almost unbelievable blow to the industry. But these men were tough and courageous. The cattle industry came back and it came back strong, but strangely enough, very few people believed yet that shelter should be provided for livestock in winter. Very few believed that it was necessary to provide supplemental feed. One rancher in the Yakima Valley of Washington put up stacks of hay in the middle 1860's and did not use any of it during a 5 year period.

So the open range idea prevailed and was generally again successful until the winter of 1880–81, which was like the terrible winter nearly 20 years before. Although the industry again suffered a devasting blow, it again came back and, as previously stated, the 1880's were some of the finest years for Northwest cattlemen. The cold waited for nearly nine years before it struck again. After the still-remembered winter of 1889–90, most cattlemen finally accepted the fact that shelter and feed were required for a good cattle operation.

When railroads came to the Northwest in the 1880's, they provided something new to stockmen. Here was something that opened up new vistas, new markets, and new opportunities. A statement in the Journal, Bismarck, No. Dak., announced that the Northern Pacific Railroad had contracted to bring 40,000 head of cattle from Washington Territory. The major market, however, continued to be Chicago. A peak price of $9.35 per hundred pounds was reached in 1882.

Things must have appeared rather rosey to cattlemen and sheepmen in the Northwest at that time. Local markets were increasing by virtue of a growing population. Foreign markets were improving, and now they had direct transportation to the beef-hungry cities of America. They were seeing the brilliant sunset just prior to the night. Already some shadows were falling.

Here and there were complaints about deterioration of the range. Soil erosion was being noted. Cattle were not doing as well in certain areas as previously. By 1885, two points were clear. First, cattle raising was no longer a frontier industry. Secondly, it was a victim of overexpansion. This overexpansion was notable at that time in Washington, Oregon, Idaho, and probably to a lesser degree in British Columbia.

The greatest blow to believers of the open-range concept was beginning to be felt—a blow to be delivered by those who believed in private ownership of land.

It must be remembered that up to this time there were few barriers that could actually prevent movement of cattle. While rivers slowed the progress of cattle, they could be crossed by swimming. Large herds often crossed from one shore of the Columbia River to the other. Large herds also were driven through mountain passes from one river basin to another. Through all of this, they had right-of-way. To obtain right-of-way across private property is often more difficult than overcoming physical obstacles.

The stockman of the open range was one of the first major users of a natural resource in the Northwest. He helped build and develop the country. He was generally a good citizen. Naturally, he felt that his way of life was good and that the open range was his. True, he and his cattle, sheep, and horses had taken it from the Indians and their horses, but he intended to keep it.

A new kind of immigrant was moving into the Northwest—people who wanted to own 160 acres to plow, plant, and harvest, to stay put and live at home. The Federal Homestead Act of 1863 gave these people the opportunity to select a homestead, improve it, and own it. As they moved in, land was fenced with barbed wire, water holes and streams were fenced from use by stock on the open range; plows turned grassland under to produce wheat, hay, and vegetables.

Railroads also took their chunk of rangeland. In order to induce and assist railroads to build into the Northwest, the Government made grants of land to railroad companies. In some cases, a company was granted every odd-numbered section (a square mile containing about 640 acres) of land for 10 miles on each side of the right-of-way. One company received every odd-numbered section for 20 miles on each side of its right-of-way in states and 40 miles on each side in territories. For a number of years, such companies allowed these sections to be used as open range, but as it became evident that overgrazing was doing damage and that these lands could be leased or sold, they were gradually removed from the open range.

As time and experience progressed, more and more was learned about grazing management. Certainly, cattlemen from Texas and the Southwest had previously seen what overgrazing had done in those areas. But every area of rangeland has its own characteristics. On the fringe of the grasslands of the Northwest grew a rugged shrub called sagebrush (*Artemisia tridentata* Nutt.). Throughout the centuries bunchgrass had conquered its own domain, but always at hand, sometimes in rocky or shallow soil or other droughty situations, but sprinkled throughout the grassland area was the ever-present sagebrush. As soon as bunchgrass gave an inch, either through overgrazing, fire, drought or erosion, sagebrush moved in. After years of such treatment, where grass had dominated the land, sagebrush had taken over. As more people occupied the area, grass and forest fires became increasingly prevalent. It seems to be a way of nature in much of the Northwest for cheatgrass (*Bromus tectorum* L.) and rabbitbrush (*Chrysothamnus* spp) to take over the soil after bunchgrasses have been burned severely. Another plague that occasionally hit the rangeland was grasshoppers. In some districts they appeared in such hordes that they consumed every blade of grass. All this reduced the stockmen's grazing resources.

As the demand for rangeland increased, men became more conscious of their individual rights and ambitions. Cattlemen fought each other for rangeland and waterholes, but most of their concern and hatred was directed towards sheep. From 1870 until the Government assumed some control of grazing lands, there was constant friction between cattlemen and sheepmen. Cattlemen maintained that sheep with their small hoofs stamped out grass and that the scent of sheep was repugnant to cattle and horses.

Following the unusually severe winter of 1889–90 and hard times of 1893, sheep began to increase rapidly. In 1892 sheep in great numbers moved into eastern Oregon and across the Columbia River into Washington (Carlson 1940).

Sheep could be fed and cared for on the range at a far smaller expense than cattle. Times were hard so the sheep were left to multiply until an acceptable market was ready. Roving bands of sheep crossing the ranges of cattlemen, often before the range was ready to use and on ranges already overstocked, led to the belief that sheep were the chief cause of range deterioration.

Roving bands of sheep on already overstocked ranges led to range wars in the 1900's. These wars chiefly centered in Crook, Lake, Wheeler and Deschutes counties in south central Oregon. The Sheep Shooter's Committee of Crook County claimed to have killed eight to ten thousand sheep a season for several years. On February 3, 1904, at Christmas Lake, Lake County, Oregon, 2,500 sheep were killed; and the remainder of a band of 3,000 were scattered. On January 1, 1905, 500 sheep were killed in Crook County.

Occasionally a sheepherder was killed. More often they were tied up and turned loose after their band was killed and scattered, with a warning not to come back. Reprisals by sheepmen were frequent. The Winchester ruled the range. Except for local outbursts, this open-range war ended in April 1906 when the U.S. Forest Service began to allot separate ranges to cattle and sheepmen. By this time,

FIG. 2. An extensive range seeding on land too depleted for native species to recover within a reasonable time through resource management alone. (Bureau of Land Management photo)

conflicts of interest were so many and so complex that controls were necessary and inevitable.

The first real move on the part of the Federal Government to control grazing was through creation of Forest Reserves in 1897. These were established under the Department of Interior where they remained until 1905 when the Forest Service was set up in the Department of Agriculture. By granting grazing permits, the Forest Service was able to limit the number of livestock on a given area and also limit the time that the range could be used. This reduced livestock on the range somewhat but gave more security to those who remained. Effective grazing laws were developed and put into effect in National Forests in 1910.

The World War I period has its effect on the range livestock industry. In their endeavor to raise more wheat, ranchers broke new ground and plowed native pastures. Large acreages were taken from native grasslands. The price of cattle and sheep increased. It appeared that prosperity was here. Good times that followed promoted a feeling of animosity toward the control of rangeland grazing. The depression of the 1930's, the country-wide drought, and the visible destruction of the range, however, brought about a change in attitudes. By the middle 1930's the public was ready for controls.

In 1933, the Soil Erosion Service was established in the Department of Interior. It was transferred to the Department of Agriculture in 1935 and renamed the Soil Conservation Service. Following a period of conservation demonstrations, soil conservation districts were gradually established under state laws and with local leadership. These districts included farmland, rangeland, woodland, and watersheds. Farmers and stockmen became cooperators in making long-range plans for conservation use, development and management of their range and related resources with technical help from the Soil Conservation Service.

In 1934, Congress passed the Taylor Grazing Act which placed administration of unappropriated public lands under the Division of Grazing, which later became the Grazing Service and then the Bureau of Land Management under the Department of Interior. This Act read in part as follows: "Administration of grazing lands . . . . insofar as grazing is consistent with the withdrawal . . . and to regulate occupancy and use of grazing land: to preserve the land and its resources from destruction or unnecessary injury, to provide for the orderly use, improvement and development of the range; and to continue study of erosion and flood control, and to perform such work as may be necessary to amply protect and rehabilitate the range." This was one of the major laws passed by Congress in the interest of range rehabilitation and development (Fig. 2).

During World War II most of the regulatory and conservation agencies carried on although with limited manpower. Their continued activity helped prevent unwise use and exploitation such as had developed during World War I. Since the middle 1940's, Federal, state, and local conservation and development agencies truly have become effective. State universities and experiment stations have contributed much to research, education, resource planning and development. Farmers, ranchers, and urban people have increased their participation in the conservation movement. The public has shared the cost of conserving the Northwest's resources through the Agricultural Conservation and Stabilization Service.

In British Columbia, there was no active control of grazing on public lands until 1919 when the Grazing Act was passed. By then the preferred ranges were overstocked and badly deteriorated. These problems were partially solved by opening up some less accessible lands which had been previously untouched. Grazing on all Crown lands, whether included in a provincial forest or not, is administered by the B.C. Forest Service under provisions of the Grazing Act. This is carried on by the Province rather than the Dominion Government. In this respect the British Columbia Forest Service performs the combined functions of the U.S. Forest Service and the Bureau of Land Management. Assistance in rangeland conservation to private land owners has been provided primarily by research workers and, only recently, by an extension range specialist.

In conclusion it may be said that at first there was the land, the grass, and the water. As time went on, rangelands became overgrazed, the forage dwindled because of conflicts of interest and overexpansion of the livestock industry. To satisfy the many interests and to rehabilitate the range and promote good conservation practices, Federal, state, and private administration, planning, development, and management became a necessity. Under public administration of these laws and through cooperation between stockmen, other users, and administrative agencies, livestock grazing on rangelands in the Pacific Northwest will continue to be one of the strong basic industries in the economy of the region. There are many millions of acres of private and public rangeland and grazable woodland in the Pacific Northwest on which concurrent grazing of livestock and wildlife should continue to be one of the major uses made of the resource.

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Grazing in the Middle East: Past, Present, and Future[1]

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Highlight

Grazing of native range lands by domestic livestock began in the Middle East, probably about 11,000 years ago. Too early and too heavy grazing doubtless occurred locally since earliest times but for many millennia the pressure of man and his animals had only limited impact on the environment. Within the last century unmanaged grazing increased greatly. Depletion is now serious over much of the area. Lack of management is not due to lack of a technical, legal, or administrative basis for action but rather to lack of appreciation of the seriousness of the problem and lack of desire to act. The primary aim of technical assistance should not be to provide more technical knowledge. Local understanding of the range problem and determination to find workable solutions are the urgent needs.

The Beginnings

The history of grazing of native forage producing lands by domestic livestock began in the Middle East. It was in the foothills or "hilly flanks" of this region that the domestication of grazing animals began probably about 11,000 years ago (Butzer, 1964; Ucko and Dimbleby, 1969). There is good archeological evidence that the goat existed as a domestic animal at many settlements in what is now Iran, Iraq, Jordan, and Israel before the seventh millennium B.C. (Reed, 1959). Evidence indicates that sheep were first domesticated about 1,000 years later. Cattle were probably domesticated about 6200 B.C. in Greece and the horse and ass somewhat later. It is certain that all of these species were in widespread use from the Nile to the Indus more than 5,000 years ago.

The domestication of herbivores was one part of the Neolithic Revolution which still ranks as one of the most significant events of history (Langer, 1952). Other essential aspects of this "Food Producing" revolution were the beginnings of crop agriculture through the domestication of wheat, barley and other food plants and the making of pottery. These three developments made possible the production and storage of an assured food supply and freed man from the daily hunt and food gathering. They made a settled existence possible and led to the establishment of villages.

No doubt prehistoric man began to graze too many goats and to practice too early grazing in the immediate vicinity of his camps as soon as he built up his first flock. But for thousands of years this mattered little. He and his animals were too few in number to have much impact on the vast reaches of virgin rangelands (Butzer, 1964).

In this semi-arid region it was natural that early man would observe the advantages of leading water from small springs to his croplands or of taking advantage of natural flooding of wadi bottoms to grow better crops. His knowledge of irrigation and water control accumulated until he was finally able to move down to the fertile alluvial flood plains and to irrigate them with the ample waters of the great rivers. This set the stage for the Urban Revolution and the development of the cities and city-states in the many broad valleys where large scale irrigated agriculture and stock raising could be practised. The great ancient civilizations of the Indus valley, Mesopotamia, Syria, Palestine and Egypt were founded as early as 4000 B.C.

As a result of the growth in population and its concentration in the cities, man began to have more impact on his environment. Timber was cut for the construction of buildings, ships and other works and fuel was gathered for cooking, heating and the firing of bricks and pottery. Flocks must have been large enough to seriously deplete the range for scores of miles around the major cities.

The history of the ancient civilizations of the Middle East is a recurring pattern of great accomplishment and flourishing economies interrupted by decline and decay. This pattern has been repeated again and again, both in time and in space.

Some civilizations undoubtedly fell because of early man's failure to adjust to his environment. In other cases historians are convinced that the fall of the cities was the result of internal strife, loss of authority of the ruler, economic crises and finally invasion by neighboring peoples. Epidemic disease and famines also took their toll. All of these forces served to hold populations in check enough to prevent the extreme damage to the range that otherwise would have occurred. Nevertheless populations built up slowly and pressure on the resources continued.

Over the centuries this pressure had its effect. Today's traveller finds it almost impossible to believe that most of the now barren slopes and mountains with annual precipitation in excess of 12 inches were once forested. Yet ecological studies have permitted the accurate tracing of the former extensive forests of oak, juniper, pistachio and almond where only a few stunted remnants are now found (Bobek, 1968).

The influence of uncontrolled grazing is also evident. The ground cover of the depleted forests is now mainly composed of thorny, un-

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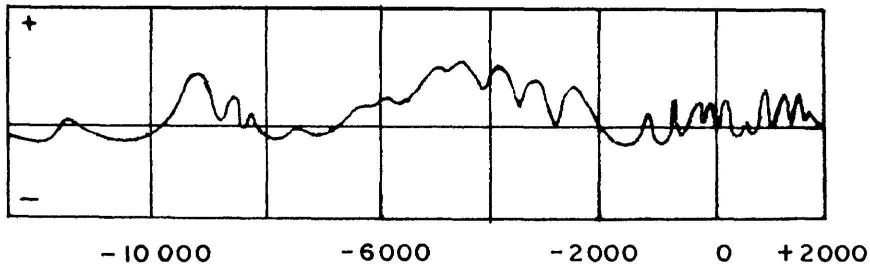

FIG. 1. Main trends of precipitation (hypothetical) in Middle East since about 12000 B.C. Source: Butzer, 1961.

palatable tragacanth species. The steppic and sub-steppic vegetation has changed from a mixture of palatable grasses, legumes and other good forage plants to low value annuals, thistles and worthless weeds.

As to the timing of these changes, detailed studies have led Bobek (1968) to conclude that "One is probably right in assuming that vegetal conditions in Iran were at their optimum during the third and second millennia B.C. There is some evidence for believing that they were much better in the first millennium B.C. and probably for a good span of time afterwards compared with conditions today. No doubt the many centuries of .... mismanagement have greatly contributed to progressive deterioration, which would seem to have accelerated in modern times." It is reported that "as recently as the sixteenth century most of the mountain slopes and uplands were covered with stands of trees, brush and grass." (Cento, 1964).

Thus the influence of man and his grazing animals began to affect the well-being of range-watershed lands from the very earliest times. Sparse populations and scattered settlement at first limited man's impact on his environment. Over the centuries the slow build-up of populations, the development of city-states and the increased exploitation of the forest and rangelands has had a marked effect on the vegetation and soil.

The possibility that climatic changes might have been responsible for the ebb and flow of civilizations and the deterioration of the vegetation must be considered. There is convincing archeological, geologic and geomorphic evidence that from the close of the sixth to the close of the third millennia B.C. the region enjoyed a period of relatively ample rainfall (Fig. 1). This was followed shortly before 2000 B.C. by a period of desiccation. The evidence indicates that for the past 4,000 years the climate of the area has fluctuated around a mean closely resembling that of the present and that the fluctuations are no more than the alternations of moist and dry years that have occurred since time immemorial (Butzer, 1961). According to Bobek (1968) "For many centuries climatic conditions in the region have not deteriorated."

Recent Developments

A trend which greatly affected the use of natural resources of the Middle East started toward the end of the last century. At about that time some central governments increased their strength and influence enough so that more political stability and economic and social progress could be achieved. Invasions and warfare began to subside. In some countries relative stability was soon reached; in others this development has been recent. Stability is still far from being accomplished throughout the region but at least the devastating invasions as well as the constant tribal raids have been held in check. And the form of strife has changed so that no longer are whole populations wiped out and their livestock destroyed.

Another recent development was the reduction of the ravages of epidemic diseases and famine through national and international public health programs.

The result of these developments has been a spectacular population build-up. In Egypt, for example, the population remained at about 3 million persons for more than 18 centuries after the time of Christ. After 1800 it began to increase, doubling by 1870. It doubled again by 1910 and again by 1950. It will reach 40 million by 1975 (Fig. 2). Similar population explosions have occurred throughout the region.

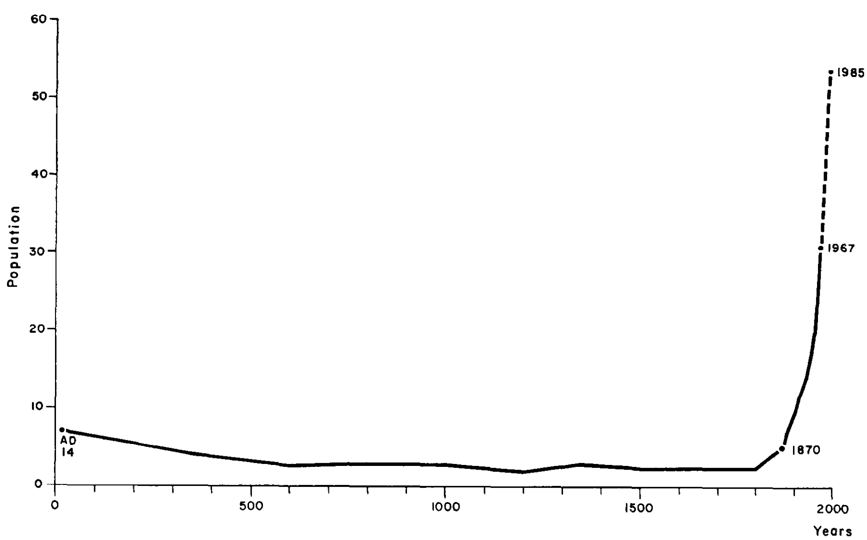

FIG. 2. Human population, Egypt, A.D. 14– 1985, in millions. Source: A.D. 14–1962, Clark, Colin. Population growth and land use. Macmillan, London, 1967; 1963– 1985 United Nations Statistical Office. New York.

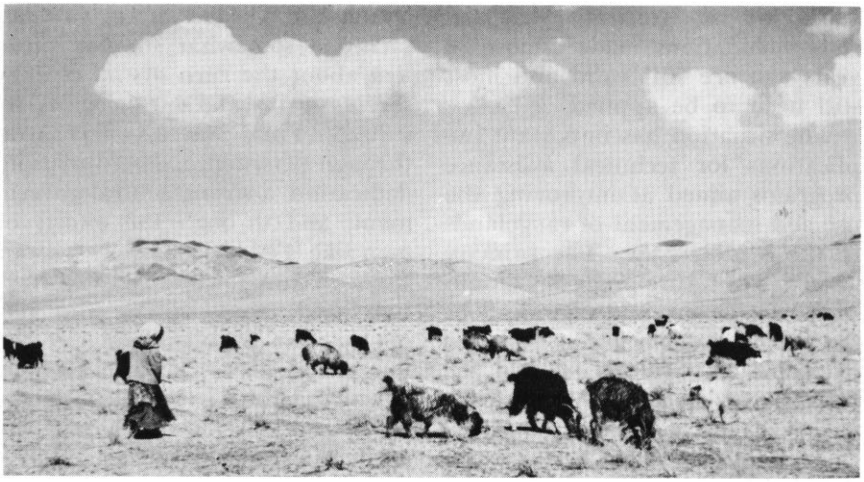

FIG. 3. Most Middle East range lands are in very poor condition as a result of recent increase in livestock numbers and lack of management. Darab, Iran.

This has brought about a corresponding increase in use of the range resource. The numbers of man's animals increased as the population increased. While records of livestock populations are scanty and often inaccurate those that are available indicate that numbers of sheep, goats and other range livestock have about doubled during the last thirty years. Figures of this order of magnitude have been quoted from Iran, Pakistan, Sudan and Turkey (Pearse, 1968; Lodge, 1965; Shepherd, 1968; Min. of Agri., Turkey, 1968).

Other factors have further aggravated the pressure on the range resource during the past few decades. These include increased fuel gathering, plowing of rangelands for cereal production, development of livestock watering places in previously unusable areas and establishment of veterinary and supplemental feeding programs which only serve to keep more animals alive to overgraze the range. It was estimated in 1964 that the number of range animals in Iran was 12 times the grazing capacity of the usable ranges (Cento 1964). A detailed study of the grazing lands of 16 Central Anatolian villages found that to avoid further damage to the range and soil 92% of the animals should be excluded (Erkun, 1964).

To summarize, it can only be concluded that Middle Eastern ranges are threatened as never before. In recent times deterioration has been rapid. It is now possible for a range technician to see the changes in a single three or four year tour of duty.

The present situation is shocking. Over vast areas there is literally nothing left to graze (Fig. 3). Erosion scars are everywhere. Microclimates have deteriorated. Soils have lost their tilth, their structure, their very life. Scarce rainfall is lost through overland flow.

The first range specialists in the region were appalled by the heavy use and lack of management. Since they thought that such grazing pressures had been operating for thousands of years they concluded that Middle East ranges must have extraordinary resistance. This conclusion was in error. Middle East ranges have been misused for perhaps several centuries but only in the past few decades has this become so serious and widespread.

The Future

With present overstocking range deterioration will continue and even accelerate. Regardless of any corrective action that may be taken the trend will continue downward on many ranges for some time to come.

There is little indication that improved range management will be applied on a significant scale in the near future. This is so in spite of the fact that technical assistance programs since the early 1950's have made good progress in developing the technical, legal and administrative basis for action.

The technical knowledge for rehabilitating most Middle East ranges and placing them under rational management already exists. In each country technical assistance studies have shown how the principles of range management developed elsewhere could be adopted and applied to local conditions (Ibrahim, 1967). In some countries corrective measures have been applied on a small scale or for a few years on jointly operated experimental or demonstrational ranges.

FIG. 4. Recovery of the better forage plants is frequently rapid following the control of grazing. *Artemisia herba-alba—Stipa barbata* with less than 200 mm precipitation. Right, grazed by village sheep; left protected two years. Rudshur, Iran.

The recovery of the vegetation under proper management has proved remarkable in many places (Fig. 4). Although continuing research is still needed, technical knowledge is now adequate to begin extensive range improvement and management programs.

The necessary legal basis for action also exists in most of the countries and could be established in others. It is true that some of the range laws are very general and means to implement them are lacking. But the legal foundation has been laid and this can give an effective basis for action.

Range departments, services or other administrative bodies have been established. These bodies are charged with the tasks of conducting research, carrying out surveys and preparing management plans. They are empowered to make and enforce regulations for the control of grazing. In most cases these units need strengthening and additional budget and staff but the organization has been established.

Lack of trained local technicians to staff the range departments and to carry out the management programs has been cited as a reason for lack of progress. While this may be a factor, it does not appear to be necessarily limiting. Hundreds of selected young men have received training in range management and related fields. Many have earned B.Sc. or higher degrees. Many are capable and have returned from their training with a strong desire to act. But too often they soon begin to feel that their chosen field lacks support and they either give up or move to more rewarding fields.

Lack of progress does not appear to be due to lack of an effective basis for action but rather to failure to recognize the seriousness of the range problem and lack of desire to attack it. There seems to be no other explanation for the failure to put into effect the recommendation of the hundreds of technical assistance reports that have been submitted to the governments (Ibrahim, 1967). It is significant that the recommendations made almost 20 years ago are still valid and most still need to be applied.

The situation has important implications for technical assistance programs aimed at improving the use and management of rangelands in the Middle East. The primary objective of future programs should be to foster an understanding of the range problem and a desire to overcome it. Efforts should be focused on making the people aware of the widespread and extreme depletion of the range-watershed lands, of the serious effects on the national well-being, and of the need for and possibilities of corrective action. All of the people, from the man on the street, to the livestock owner, to the highest government official need to be convinced.

How best to do this deserves much thought. Perhaps a few well conceived demonstration ranges where grazing could be controlled and good management applied over a long enough period to show the responses would be effective. Operation would have to be continued for at least ten years regardless of changes in personnel or policies. Full control of the land and the animals must be in the hands of the technicians. The objective should be clearly understood to be demonstration of good range management, not research or testing.

Perhaps there are other new ways through which technical assistance could help in an attack on range problems. One might be to assist in applying good management on a few carefully selected grazing allotments provided that the government agreed that this was desirable. All possibilities should be carefully explored. Continued use of the traditional approaches will not be effective except to the extent that they help to develop interest and stimulate a desire for action.

Whatever is done the difficulties ahead cannot be overestimated. Long established tradition, vested interests, and delicate political balances all combine to delay change. When the United States first attacked a somewhat similiar problem about the turn of the century severe strains and bitter fights resulted. Final success was won through persistence, determination, dedication, a strong central government, and through the efforts of men like Teddy Roosevelt, Gifford Pinchot, Jim Jardine, W. C. Chapline, and many others who recognized the problem and put the long term needs of society above personal ambitions and expediency. The same prerequisites will be needed in the Middle East.

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Lehmann Lovegrass on the Santa Rita Experimental Range, 1937-1968[1]

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Highlight

Thirty years' experience shows that Lehmann lovegrass readily establishes itself from seed under adverse conditions, reseeds itself quickly after fire or other disturbance, can withstand heavy continuous yearlong grazing, and can invade established stands of velvet mesquite. However, it is less palatable than native perennial grasses during the summer growing season, and has almost completely replaced the native perennial grasses on and adjacent to seeded areas within its preferred range.

Resumen[3]

El Zacate Lehmann Lovegrass en la Estacion Experimental de Santa Rita Durante los Años de 1937–68.

Los estudios se llevaron a cabo en la estación experimental de Santa Rita cerca de Tucson, Arizona, EUA. Se encontró después de 30 años de observaciones que el zacate Lehmann Lovegrass (*Eragrostis lehmanniana* Nees A-68) tiene buena adaptación a las zonas de 1,100 a 1,500 metros de altura y que tengan precipitación pluvial de 225 a 325 mm.

Las siguientes ventajas y desventajas fueron encontradas:

1) Existe menor palatabilidad del zacate en el verano y mayor en el invierno que los zacates nativos.
2) El forraje seco dura mas que los nativos de un año a otro por lo tanto su uso es ventajoso para sequías.
3) Es muy agresivo ya que puede reemplazar las especies nativas e invadir montes de mezquite y tierra quemada.
4) Puede resistir el pastoreo pesado y continuado por todo el año.

Lehmann lovegrass (*Eragrostis lehmanniana* Nees A-68) has been widely used to revegetate the drier portions of southwestern ranges and burned areas on national forests and other public and private lands since its introduction into the United States in the early 1930's (Crider, 1945). First planted on the Santa Rita Experimental Range, 30 miles south of Tucson, Arizona, in 1937, this species was used in numerous revegetation trials between 1945 and 1954 to determine its adaptability to varying soil and rainfall conditions and to various seeding methods. Most of these plantings were between 3,400 and 4,100 ft elevation, with annual rainfall from 13 to 17 inches (60% summer). A few areas were planted at elevations between 2,900 and 3,300 ft, with from 10 to 12 inches annual rainfall. Continuing observations and measurements of these plantings have revealed many of the strengths and weaknesses of Lehman lovegrass as a forage grass.

The usual objections to Lehmann lovegrass are: (1) it is less palatable than native perennial grasses during the summer growing season, and (2) on areas where it is well adapted, it eventually dominates the stand and reduces the native grasses over a period of years to a very minor component.

On the strong side: (1) Lehmann lovegrass readily becomes established from seed under adverse conditions, (2) it reseeds itself quickly after fire or other disturbance, (3) it can invade established stands of velvet mesquite (*Prosopis juliflora* var. *velutina* (Woot.) Sarg.) and produce relatively high yields of herbage, (4) its herbage carries over from one year to the next in better physical condition than that of natives for use as emergency forage, (5) it produces more green herbage during the winter and early spring than most native perennial grasses, and (6) it withstands repeated close grazing.

Although the above listing classifies the various attributes of Lehmann lovegrass as either strong or weak, most attributes have both desirable and undesirable implications for land managers.

Palatability

Cattle definitely prefer the predominant native perennial grasses to Lehmann lovegrass during the summer growing season. During the winter, however, the lovegrass remains greener than native grasses and is grazed readily. Cable and Bohning (1959) concluded that differences in palatability were as great among the several native perennials on the Santa Rita as between Lehmann lovegrass and native grasses. The relative palatability of lovegrass also changes following cultural treatment. In a high rainfall summer, Holt (1959) found that cattle grazed all grasses —native perennial grasses, Lehmann lovegrass, and annual grasses—indiscriminately, where 25 lb./acre or more of nitrogen was spread. More recently, the newly established lovegrass on an area accidently burned in April 1969 was grazed more closely in the following early fall than was mature lovegrass on adjacent unburned range. Thus, palatability of Lehmann lovegrass, while variable, is generally low, and this can be an advantage where grazed ranges are being seeded.

Ease of Establishment

The ease with which Lehmann lovegrass becomes established is one expression of its aggressiveness. Characteristically, broadcast plantings on unprepared seedbeds produce sparse initial stands that thicken up to dense, almost pure,

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FIG. 1. Small-diameter lovegrass plants on area grazed heavily yearlong (25-cent piece for scale).

stands of lovegrass over a period of from 5 to 15 years. On the Santa Rita Lehmann lovegrass had been broadcast seeded successfully on unprepared seedbeds above about 3,500 feet elevation, and 13 to 14 inches annual rainfall. Establishment has been poor at 2,900 feet with under 10 inches annual rainfall. Stands established at elevations from 3,000 to 3,400 feet are thin and show little or no spread except along water courses.

The ability of Lehmann lovegrass to establish itself from seed after fire or heavy grazing is outstanding. A small fire in an exclosure in June 1963 burned a nearly pure stand of lovegrass and an adjacent area dominated by black grama (*Bouteloua eripoda* Torr.). The fire killed 98% of the lovegrass plants and 90% of the black grama plants (Cable, 1965). No black grama seedlings were established during the immediately following summer rainy season, but by fall, new lovegrass plants had not only reoccupied the lovegrass area (17 new plants/ft^2) but 13 new lovegrass plants/ft^2 had become established on the former black grama area in a nearly pure stand. Six years later, the former black grama area was still a nearly pure stand of fewer but much larger Lehmann lovegrass plants.

Lehmann lovegrass also has become established and is maintaining itself near stock water where it is grazed closely yearlong. Because of repeated close grazing, most lovegrass plants probably live only 1 or 2 years, but new plants become established each year to maintain a high density (5 to 20 plants/ft^2) of small-diameter plants (Fig. 1). The relatively low palatability of lovegrass during the growing season and its habit of producing seedstalks early in the summer enable it to maintain itself under heavier grazing than native perennial grasses can stand.

Natural Spread of Lovegrass

The spread of Lehmann lovegrass under natural conditions is well documented in the record of its occurrence on herbage production and utilization transects on the Santa Rita. From 10 to 20 of these transects (a total of 239) are located in each pasture and are visited at least twice yearly. Lovegrass was recorded on only four transects in 1955, compared to 14 transects in 1962 and 65 transects in 1968. Lovegrass plantings are as close as 0.1 mile to some transects, and as much as 3 miles from others. Lovegrass has spread most commonly onto transects at the higher elevations (4,000 ft +) and within 0.5 to 0.75 mile from a seed source.

The natural spread of Lehmann lovegrass is illustrated also by records from 1954 to 1968 in a 754-acre pasture having a sparse mesquite stand. The pasture varies from 3,700 to 4,100 ft elevation and receives 14 to 16 inches annual precipitation. Small plots of Lehmann lovegrass were planted in this pasture in 1950, 1951, and 1953. Lovegrass was first recorded on one of the herbage production transects in 1955. By 1968 it was reported on all 10 transects and as much as 0.4 mile from the nearest seeded plot. Average production of lovegrass between 1955 and 1960 ranged from 2 to 55 lb./acre for the pasture, and varied in response to summer rainfall. From 1960 to 1968, lovegrass production increased, independently of changes in summer rainfall, from 12 lb./acre to 331 lb./acre, a change from 3% of the total perennial grass production in 1960 to 66% in 1968 (Fig. 2). Native perennial grass yields also increased between 1961 and 1967, but would probably have been even higher had the lovegrass not been present. The relatively large drop in native perennial grass production in 1968, despite better-than-average rainfall, may represent the first step in declining native perennial grass production due to lovegrass competition.

Competition With Native Vegetation

Lehmann lovegrass has an unusual ability to invade existing stands of native perennial grasses and shrubs, and, in the process, to replace most of the native perennial grasses. Concern over this possibility, expressed by Humphrey (1958), appears to have been well founded. On the Santa Rita, production of associated native perennial grasses has declined drastically on areas where Lehmann lovegrass has formed dense stands.

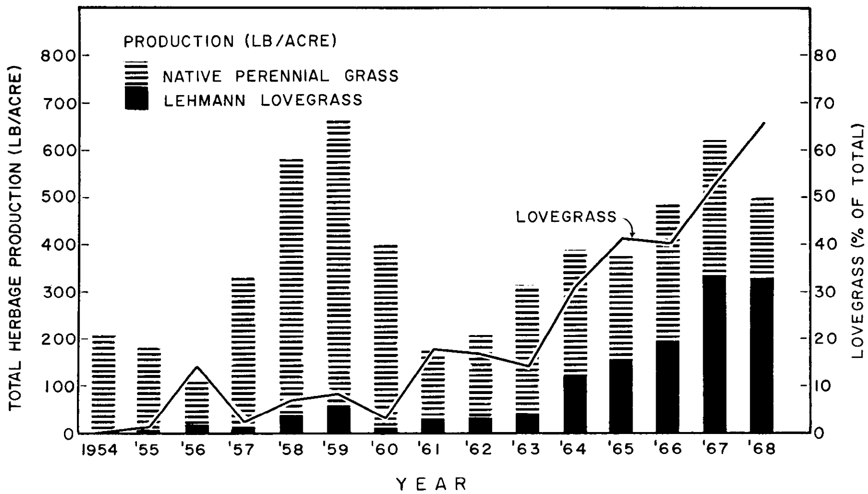

FIG. 2. Changes in production of native perennial grasses and Lehmann lovegrass in a 754-acre pasture, 1954–1968.

One study involves four sites at elevations from 3,150 ft to 4,100 ft established to study the influence of mesquite density on perennial grass production. At each site, one 2-acre plot was left with an undisturbed stand of mesquite, and four adjacent plots were thinned to leave 25, 16, 9, and 0 mesquites/acre (mesquite density on the check plots varied from 44 trees/acre at the lowest elevation to 358 at the highest). A narrow strip across one end of each plot was seeded to Lehmann lovegrass in 1945. Herbage production was measured annually from 1946 to 1950, and in 1958 and 1968.

Lovegrass spread over the plots most quickly at the highest elevation, where growing conditions were most favorable, and more slowly at each successively lower elevation. The lovegrass remained within the seeded strips until some time after 1950. By 1958 it had spread to the opposite end (400 ft away) of some plots at all four elevations. In 1968, the abundance of lovegrass at the lowest elevation was still too low to interfere with native grasses, but its abundance at the other elevations had seriously reduced the production of native perennial grasses (Fig. 3).

Lovegrass is much better able to compete or co-exist with mesquite than are the native perennial grasses, whose yields typically vary inversely with mesquite density. In 1968, for example, lovegrass at the highest elevation produced essentially as well on the check plot, with 358 mesquites/acre, as on any of the other plots. At 3,700 ft, with lower rainfall, lovegrass yields were about the same on plots with up to 25 mesquites/acre, but significantly lower on the check plot with 138 trees/acre. The decline in native perennial grass production between 1958 and 1968 at the two higher elevations suggests that the lovegrass was depressing the native perennial grass yields in 1968 as much or more than the mesquite did before thinning.

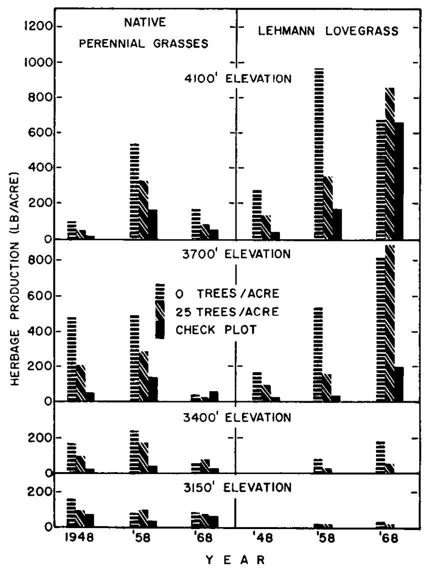

FIG. 3. Changes in production of Lehmann lovegrass and native perennial grasses on 2-acre plots with three mesquite densities, at four elevations, 1948–1968 (lovegrass production for 1948 is for seeded strip only).

At the two lower elevations competitive relationships between lovegrass, mesquite, and native perennial grasses are less clear.

Dominance of Lehmann lovegrass in 1968 increased generally with elevation. Lovegrass made up only 21% of the perennial grass production at 3,150 ft, 49% at 3,400 ft, and 95% and 88%, respectively, at 3,700 and 4,100 ft (Table 1). Arizona cottontop (*Trichachne californica* (Benth.) Chase) and three-awn grasses (*Aristida* spp.) sustained most of the loss in native perennial grass production during the study period at the 3,700 ft-site (Fig. 4). Slender grama (*B. filiformis* (Fourn.) Griffiths), sprucetop grama (*B. chondrosioides* (H.B.K.) Benth.), side-oats grama (*B. curtipendula* (Michx.) Torr.), and Arizona cottontop sustained most of the loss at the 4,100-ft. site.

Lehmann lovegrass has also increased rapidly in a 150-acre pas-

Table 1. Percentage of total perennial grass production contributed by Lehmann lovegrass in 1968.

Mesquite Density (trees/acre)	Percent production by elevation (feet)			
	3150	3400	3700	4100
0	14.0	73.9	96.0	80.5
9	40.7	46.2	94.8	89.0
16	23.0	35.8	98.2	88.0
25	8.2	42.9	98.8	90.9
Check	6.7	0	76.1	92.8
Mean	20.8	48.8	95.4	88.2

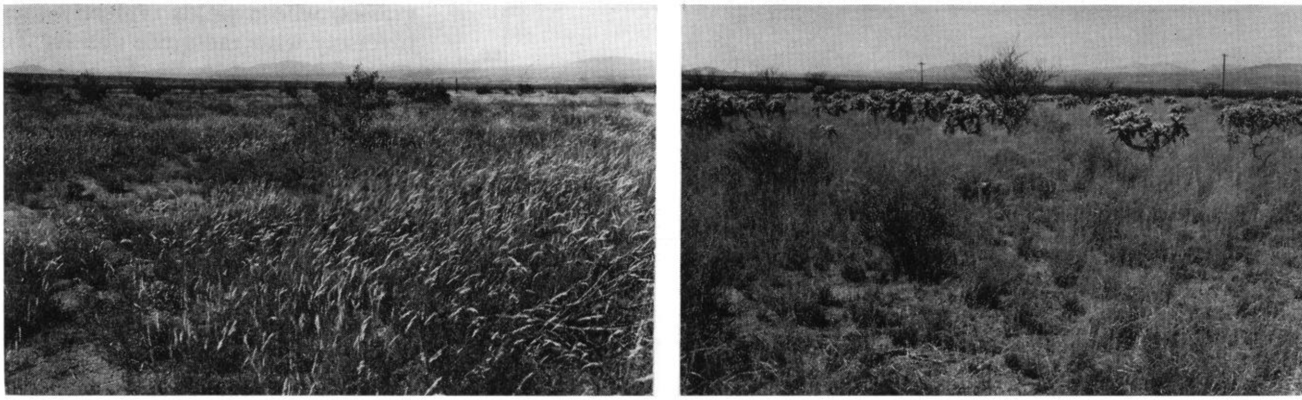

FIG. 4. Change in grass composition on plot with 9 mesquites/acre at 3,700 ft elevation. Left: In 1946, two growing seasons after mesquites were thinned, Arizona cottontop formed a thick stand. Right: In 1969, a nearly pure stand of Lehmann lovegrass.

ture at about 3,800 feet elevation on the Santa Rita. The mesquite on 100 acres of the pasture were controlled by aerial spray of 2,4,5-T in 1954 and 1955, and 1 lb./acre of lovegrass seed was broadcast over the entire pasture from the air in 1954. In 1955, total perennial grass production on the sprayed area was 914 lb./acre, of which lovegrass made up 110 lb., or 12% (Fig. 5). In the ensuing 13 years, native perennial grass production decreased an average of 62 lb./acre for every 100 lb./acre increase in lovegrass production, until in 1967 lovegrass produced 978 lb./acre and native grasses only 130 lb./acre (below pre-spray yields). The native perennial grasses that sustained most of this loss were Arizona cottontop and plains bristlegrass (*Setaria macrostachya* H.B.K.).

On the unsprayed part of the pasture lovegrass spread much more slowly, but from the 11th year (1964) on the native grasses produced about 175 lb./acre (not greatly different from the level of production before lovegrass was seeded), and lovegrass about 600 lb./acre. In this situation lovegrass yields provided a forage bonus by filling a niche that native perennial grasses did not fill in competition with mesquite.

Yearlong stocking in this pasture averaged 2.3 head during the 10 year period before seeding and mesquite control. From 1955 to 1965, after spraying and seeding, stocking averaged 6.3 head. The nearly threefold increase in average stocking is attributed mainly to increased forage production resulting from mesquite control, although in later years increases in lovegrass on the unsprayed part of the pasture have provided an extra increment of carrying capacity.

Grazing and soil appear to have had little influence on the spread of Lehmann lovegrass on the Santa Rita. Lovegrass has replaced native perennial grasses on areas continuously protected from livestock, on areas grazed heavily yearlong, and on areas grazed at various seasons and intensities between these extremes. Likewise, Lehmann love-

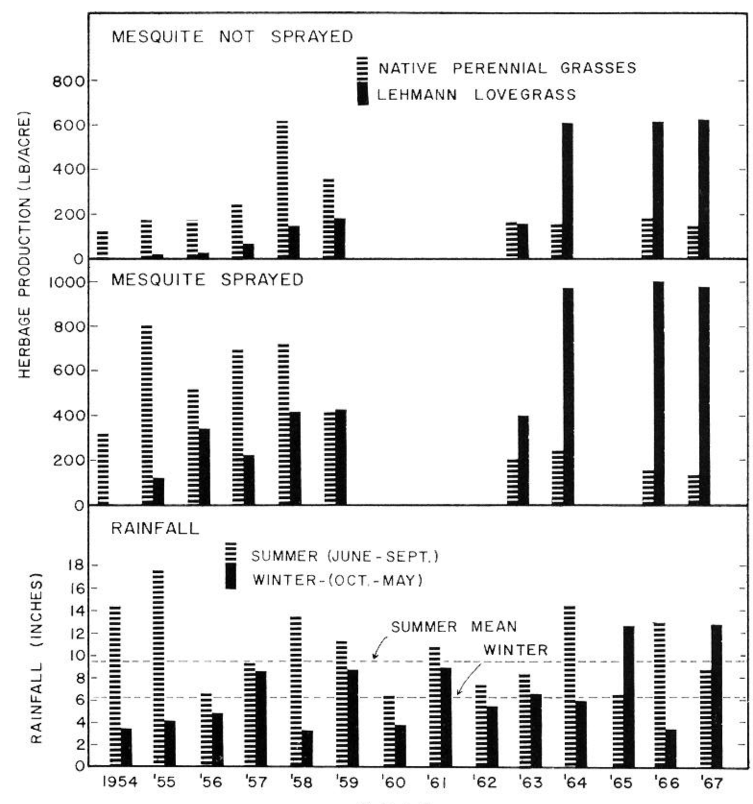

FIG. 5. Changes in herbage production of native perennial grasses and Lehmann lovegrass on sprayed and unsprayed range seeded in 1954.

grass has developed into dense stands on a variety of soils including sandy loams, gravelly loams, and stony loams of the Continental, Comora, Sonoita, Tumacacori, and White House series (Youngs et al., 1936).

Carry Over Herbage

The value of Lehmann lovegrass as an emergency forage was demonstrated in 1965, when summer rains on the Santa Rita were light. For the want of forage, the 58 cattle from a 4,900-acre pasture, where annual grasses normally produce most of the forage, were moved August 10 into the 150-acre sprayed and reseeded pasture mentioned previously. Herbage production in 1965 was relatively low, but there was an accumulation of old growth on the lovegrass clumps, and lovegrass made up over 80% of the available grass herbage. The cattle were kept in the pasture for 2.5 months, during which time they grazed the lovegrass to a relatively uniform stubble height of about 2 inches. The mature cattle did well during this period of intensive use, although the rancher felt that the calves were a little lighter in the fall than calves on adjacent native range. No harmful effects of the heavy use were apparent in the lovegrass growth the following summer.

Ungrazed lovegrass plants are particularly conspicuous in years of high forage production because of their low palatability during summer, and the consequent tendency for old growth to accumulate. This ungrazed herbage can provide drought insurance for the rancher, however, and should be a source of comfort rather than a cause for alarm.

Cool-Season Herbage

The green lovegrass foliage produced in the winter, although present in much smaller volume than in summer, probably provides grazing animals with a more nutritious diet than is provided by native grasses alone at this season. Not only is the volume of green lovegrass herbage greater than that of the natives in winter, but its crude protein content averages from 11% to 38% higher than that of Arizona cottontop, the dominant associated native perennial grass (Cable and Shumway, 1956).

Summary and Conclusions

Records of the occurrence and spread of Lehmann lovegrass on the Santa Rita Experimental Range between 1937 and 1968 indicate that:

1. Lehmann lovegrass is well adapted to semidesert ranges between about 3,500 and 4,500 ft elevation, and 13 to 17 inches of annual rainfall; it often develops into almost pure stands, and crowds out the more palatable native perennial grasses.
2. At lower elevations, and 13 inches or less rainfall, lovegrass persists in scattered stands, spreads very slowly, and appears to be no great threat to native perennial grasses.
3. Within its preferred range, Lehmann lovegrass establishes itself fastest on areas with little or no competition from native perennial grasses or mesquite. It will establish itself from seed broadcast into stands of mesquite, however, although it may take 10 to 25 years to reach a production of 200 lb./acre, compared to as few as 2 years where mesquite is controlled.
4. Lehmann lovegrass plants are easily killed by fire, but new plants become established quickly from seed already in the soil.
5. Lehmann lovegrass becomes established more quickly on semidesert ranges than any other perennial grass species that has been tried on the Santa Rita, and is the only perennial grass that has demonstrated the ability to establish itself in a mesquite stand or on heavily grazed areas.
6. In the final analysis, the decision whether or not to plant Lehmann lovegrass must be based on an evaluation of its strengths and weaknesses in relation to the local situation. If it is planted, it should be with the expectation that it will eventually develop into a nearly pure stand, and will spread to adjacent range.

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Increasing Utilization of Weeping Lovegrass by Burning[1]

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Highlight

Burning increases the production and cattle preference of weeping lovegrass. A winter burn increased spring and summer herbage yields of weeping lovegrass 14% and utilization 53%. Burning increased crude protein from 3.6% on untreated lovegrass to 7.6% on unfertilized burned plots. It increased crude protein content from 5% on unburned fertilized plots to 10.5% on burned fertilized plots. Forty-four pounds per acre nitrogen fertilization increased crude protein but had little effect on forage production and utilization.

Resumen[2]

Estudio Sobre el Uso de Quema y Fertilizantes para Aumentar el Pastoreo de Weeping Lovegrass

Weeping lovegrass (*Eragrostis curvula* (Schrad.) Nees) tiene buena adaptación a varios climas y suelos, especialmente suelos arenosos. Este zacate tiene menor palatabilidad. Este estudio se llevó a cabo en la granja experimental de Texas Tech cerca de Amarillo, Texas, E.U.A., se demostró que puede aumentar la palatabilidad del zacate con quema. La quema durante invierno aumentó la producción de forraje en un 14%, la intensidad de pastoreo en un 53%, y el contenido de proteína en un 3.4%. La fertilización de nitrógene a 44 Kgs/Ha. aumentó el contenido de proteína pero no influyó en la producción de forraje ni en la palatabilidad del zacate.

This study was conducted to determine the effects of burning and fertilization on production and utilization of weeping lovegrass (*Eragrostis curvula* (Schrad.) Nees). Weeping lovegrass has been seeded extensively throughout the southern United States since its initial introduction in 1927 from Tanganyika, South Africa (Hoover et al., 1948). It is readily adapted to a wide range of climate and soils, especially on sandy soils of the southwest. Weeping lovegrass that can withstand extended drought periods (Staten, 1952). Its ability to survive high summer temperatures and winter temperatures as low as –11 F has led to its use as an erosion control grass (Staten, 1952).

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[2] Por Dr. Donald L. Huss, Organizacion de las Naciones Unidas para la Agricultura y la Alimentacion (FAO), Dep. de Zootecnia, ITESM, Monterrey, N. L. Mexico.

Weeping lovegrass grows quickly, and if planted in April, can be grazed about the first of the following July (Staten, 1952). Although a warm season grass, seed can mature as early as June, and growth generally subsides with hot weather.

Palatability is its weakest point. Grazed readily by cattle during the early growth period, its palatability drops off sharply as it reaches maturity. Spring controlled burning and fertilization improved early forage quality and increased forage production in Oklahoma (Dalrymple, 1968). The use of fire as a management tool for weeping lovegrass needs study on deep hardland sites of the Southern High Plains.

Study Area and Procedures

An established 14 acre weeping lovegrass stand planted in May 1967 on the Texas Tech University Research Farm 14 miles east of Amarillo was used for the study. The vegetation consisted primarily of seeded weeping lovegrass, although Kochia (*Kochia scoparia*), Johnson grass (*Sorghum halepense*), and silver bluestem (*Andropogon saccharoides*) were present in small amounts. The soil is a Pullman silty clay loam, the major soil of the deep hardland sites in this region (Mathers, 1963). The climate is typical of the High Plains with high summer and low winter temperatures. Precipitation averages 19 inches, coming mostly during the spring and fall. Desiccating winds occur year round and commonly reach velocities of 35 mph.

The study area was divided into 4 plots. Two plots were burned on January 2, 1969. One plot each in the burned and unburned areas received 44 lbs. of nitrogen per acre by applying 200 lbs. of bulk ammonium sulfate. Fertilizer cost was $5.60 per acre. The plots were grazed from May 27 to June 9 with 5 heifers and one bull. To determine herbage yield and utilization, ten randomly located, paired, caged and uncaged 4.8 ft^2 plots were clipped in each of the four treatments (Fig. 1). Crude-protein was determined by the Kjeldahl method.

Forage Production

Nitrogen fertilization did not significantly increase production (Fig. 2). An inconsistent growth pattern contributed to this behavior. The weeping lovegrass made some growth during April, but growth tapered off rapidly before rains in May relieved dry soil conditions. The fertilizer appeared to have had detrimental effects on the weeping lovegrass during the early dry period. A noticeable cessation in growth and a marked deterioration of the new growth was observed on May 2. This effect was more evident in the fertilized plots.

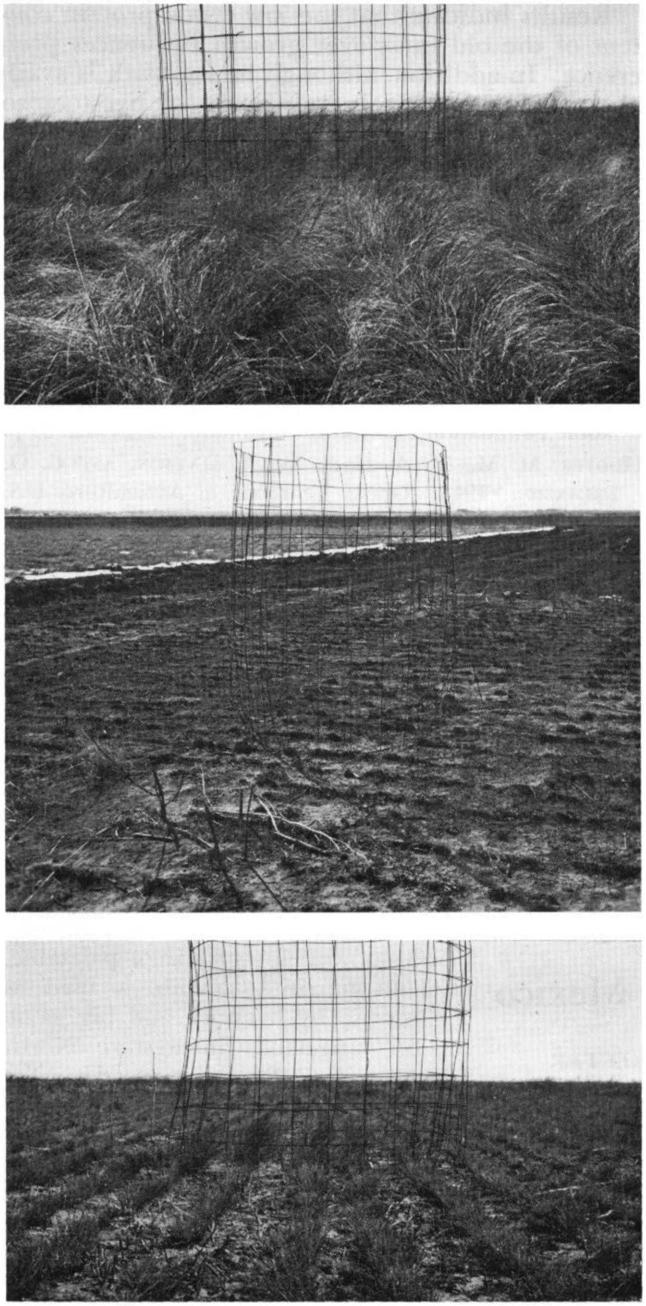

FIG. 1. Upper: Unburned weeping lovegrass showing dead carryover growth from previous growing season: Middle: Burned weeping lovegrass area in foreground shows complete removal of old growth. Lower: The burned area produced more than the unburned area and was preferred by cattle.

Herbage production was significantly higher (14%) on the burned plots. Burned plots averaged 332 lbs. more forage per acre than unburned plots (Fig. 2). These production figures represent growth only for the period January 2, 1969, to June 10, 1969, yet production on burned plots surpassed that of previous studies on unburned plots in this area (Whitfield et al., 1949).

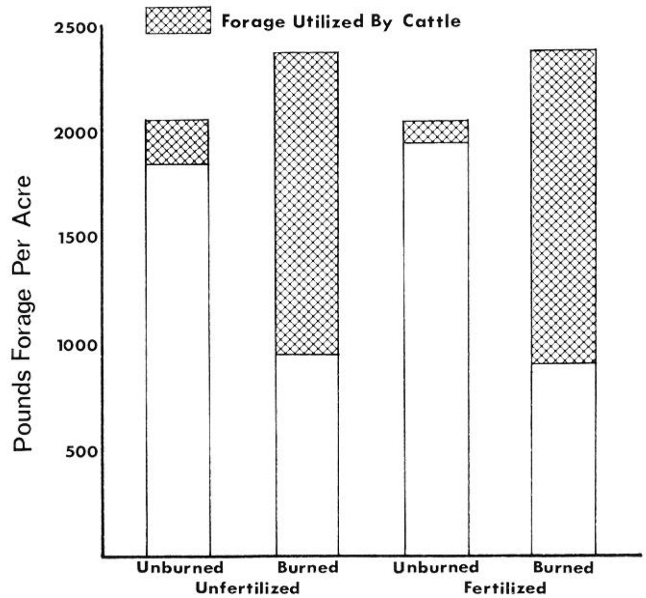

FIG. 2. Pounds of oven-dry forage and utilization of weeping lovegrass with various treatments.

Utilization and Preference

Nitrogen fertilization had no influence on grazing preference on either burned or unburned areas but burning greatly increased utilization

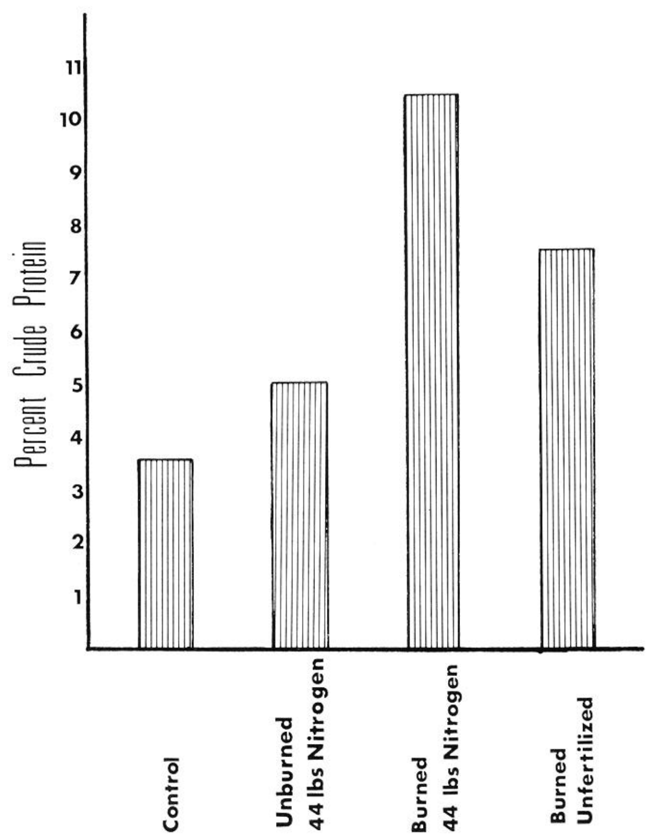

FIG. 3. Percent crude protein of weeping lovegrass samples collected June 10, 1969.

(Fig. 2). At the end of the 14 day grazing period the cattle had grazed 52% of the burned weeping lovegrass but only 8% of the unburned. The lush green growth free of dead carry-over growth on the burned area contributed to this difference. Higher protein content of regrowth on the burned area could also be a factor.

Crude Protein Content

Samples from the untreated plot containing 81% carry-over growth and 19% current season growth yielded 3.6% crude protein (Fig. 3). Similar samples from the fertilized-unburned plots contained 5.0% crude protein—an increase of 1.4%. Crude protein for the green material and carry-over growth on the untreated control plot averaged 5.7% and 2.9% respectively.

The regrowth on the burned areas had significantly higher amounts of crude protein. Samples from burned and fertilized plot average 10.5% crude protein and the burned-unfertilized plot yielded 7.5% crude protein. In other studies, Whitfield et al. (1949) reported crude protein for untreated weeping lovegrass at 6.3% while Dalrymple (1968) recorded 19.7% crude protein on spring burned and fertilized plots and 11.8% on unburned-fertilized plots.

Results indicate that the low crude protein content of the old carry-over growth influences preference. In addition, although new growth is available in the bunches, it is difficult for livestock to graze. Therefore, cattle tend to leave the entire plant ungrazed. The ability of weeping lovegrass to "green up" during the winter with adequate soil moisture and warm temperatures is of little value unless the carry-over growth is first removed. Burning appears to be one method of doing this on deep hardland sites in the Southern High Plains.

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Natural Reproduction of Winterfat (*Eurotia lanata*) in New Mexico[1]

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Highlight

***In situ* ecological factors influencing the natural reproduction of the important Western browse species winterfat (*Eurotia lanata*) were investigated in central and west-central New Mexico from summer 1967 to spring 1969. Seed of winterfat germinated in late winter and early spring on all slopes and in soils varying widely in origin and texture. Survival was greatest on disturbed soils which supported low vegetation that afforded some shelter but little shading for seedlings. The disturbed soils indicated greater moisture availability. Seedlings were tolerant to competition, and were often found in living clumps of grass. A comparison of vegetation on heavily grazed and protected ranges indicated winterfat was susceptible to heavy grazing, and reproduced when on protected or lightly grazed range dominated by low-growing grasses.**

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Winterfat (*Eurotia lanata* (Pursh) Moq.), a low-growing, palatable, and nutritious shrub, is used as browse by livestock and big game on rangelands in western North America. Exploitation of New Mexico rangelands by the white man has led to the decrease, and in some cases the extermination, of valuable browse species, thereby limiting the carrying capacity of the range. Currently, in attempts to improve big game habitat, state and federal agencies are investigating the re-establishment of browse on depleted rangelands. This study was initiated to determine some of the *in situ* ecological factors influencing the natural reproduction of winterfat in the pinyon-juniper and ponderosa pine vegetational types in central and west-central New Mexico. The principle factors considered were life cycle, climate, site, soil, plant association, and animal association. The results of this study are intended to supplement

Table 1. Analysis of sites in areas of reproduction of winterfat (*Eurotia lanata*).

	Sandia Mtns., Sandoval Co.				Zuni Mts., McKinley Co. Fort Wingate	Gallinas Mtns., Socorro Co. Magdalena
	Watershed-A	Watershed-B	Fish hatchery-A	Fish hatchery-B		
Elevation (m)	1,705	1,800	1,875	2,070	2,150	2,090
Topography	Drainage bank on alluvial fan	Bottom of slope, head of alluvial fan, adjacent to head of arroyo	Slope on inside of curve of road	Slope	Canyon floor	Drainage bottom
Slope direction & percent	W 5–10	W 10–15	W 15–20	E-NE 100	N 4	SW 0–10
Parent material	Alluvium	Alluvium	Madera Ls.	Madera Ls.	Alluvium	Dune sand
Mineral soil depth (cm) and horizons	>45 A 0–11 B 11–36	>45 A 0–22 B 22–42	25	25	>45 A 0–15 B 15–?	>45 No development
Soil texture	Cherty, sandy loam	Stony, (angular) gravelly, clay loam	Stony, cherty heavy clay loam	Rocky, stony, coarse cherty, cherty, loam	Heavy clay loam	Sandy loam
Soil pH	7.6–7.8	7.6	7.4	7.6	7.6–8.0	7.9
Vegetation, total cover, all strata (%)	45	63	43	45	44	46
Trees, total cover (%)	0	0	4	1	0	0
Shrubs, total cover (%)	2	5	5	22	19	27
Herbs, total cover (%)	45	58	34	15	29	21

general knowledge of the reproduction of this important browse species, and thus lead to improved techniques of re-establishment and management practices.

Winterfat is found from Manitoba and Saskatchewan to the Pacific Coast states, east to western Texas, and north through the Great Plains. It is common in certain areas up to approximately 2,450 m (about 8,000 ft) elevation and rarely to approximately 3,000 m (about 10,000 ft). Dayton (1931) and others agree that, because of overgrazing by livestock, the species is less abundant and covers a narrower range now than previously.

Winterfat is found most abundantly in the foothills, plains, and valleys of the West. It grows in dry soils that range from sands to clays and which are often impregnated with white alkali and other salts. Associated vegetational types range from desert plains and scrub to ponderosa pine, mountain parks, and mixed-grass prairie. The species is usually associated with desert scrub, semidesert bunchgrasses, sagebrush, and pinyon-juniper. It is frequently abundant and widespread, sometimes becoming the dominant (Dayton, 1931).

Winterfat is very nutritious and palatable for all classes of livestock and game herbivores (Van Dersal, 1938; Jameson, 1952; Cook et al., 1959). All parts of the plant above the woody base are eaten by the animals. Riedl et al. (1954, p. 10) state, "in August the nutritive content (of winterfat) may be higher than that of a good grade of alfalfa hay."

Field Work and Methods

This study was made from the summer of 1967 through the spring of 1969. Detailed investigations were conducted during the summer, and supplementary field observations were continued throughout the year.

The predetermined study areas were on, or adjacent to, the Cibola National Forest in the Sandia Mountains in Bernalillo and Sandoval counties, Gallinas Mountains in Socorro County, and the Zuni Mountains in western Valencia and southern McKinley counties. These areas were selected because they provide a wide variety of surface rock formations, soils, and topography (Table 1).

Two terms, as used in this study, require definition: *Microenvironment* is the environment within a 1 m² quadrat frame centered over a seedling. *Seedling* is a plant up to about two years old growing in a microenvironment similar to the one in which it germinated. Determination of seedling age by counting terminal bud scale scars is not possible with this species. Age determination in the absence of cotyledons is indecisive without careful inspection of annual rings, which are indistinct in winterfat. Plants were not cut for ring counts since seedlings were scarce on some sites and were needed for long-term survival studies. Less reliable but non-injurious examination of morphological characteristics was used to determine approximate seedling age.

Soil profiles of the upper 45 cm, or to bedrock if shallower, were characterized by describing pits near the study plots. Soil classifications of texture, coarse fragments, stoniness, and rockiness were based on the U.S. Dep. Agr. Soil Survey Manual (1951). Soils were classified primarily by observation, with verifications of texture made by the hydrometer method of Bouyoucos (1936). Information on Zuni Mountain soils was supplemented by Williams (1967). The pH of soils was determined with a La Motte-Morgan soil testing kit.

Two methods were used for analyzing total cover of vegetational foliage, rock or large stones, and litter. Total foliage cover was measured rather than basal cover because the foliage of the surrounding plants is generally the dominant feature providing shelter and shade for the seedling microenvironment. A 1 m^2 quadrat frame was centered around a seedling, with the sides oriented to the four cardinal compass points. The plot thus delineated the seedling microenvironment defined above, and chart quadrats were then drawn. Representative plots were selected to be used in seedling survival studies, and were permanently marked by painted metal stakes with plastic flagging at two diagonal corners of the plot. These permanent plots were examined periodically from the time of location through early spring 1969, and notes were taken regarding survival and the observable factors affecting survival. Plants were identified whenever possible and placed in one of three strata: 1) *grass-forb layer*—grasses, forbs, and young shrubs and trees not taller than the surrounding grasses and forbs, 2) *shrub layer*—all shrubs and those trees taller than stratum (1) but less than 1.83 m (6 ft), and 3) *tree layer*—trees taller than 1.83 m (6 ft).

FIG. 1. Fenceline contrast of range condition and winterfat reproduction between Bernalillo Watershed and Sandia Indian Reservation.

The second method of analysis utilized four 10-m line intercepts, all originating from the seedling at the center of the quadrat and running to each of the cardinal compass points. Total cover in the three strata mentioned above was measured and recorded as to distance from the seedling.

The same intercept method was used for a vegetational comparison of protected range on the Bernalillo Watershed and adjacent overgrazed range on the Sandia Indian Reservation in Sandoval County; however, plots were located in the following way rather than originating at a seedling. Three sites were selected along the fence which forms the boundary between the two ranges. Sampling plots, within each site, were placed in physiographically equivalent locations on either side of the fence at the three sites. Plots were placed so that vegetation within 1 m of the fence was not sampled to avoid the effect evident in Fig. 1. In addition to the largely quantitative methods described, detailed subjective notes were taken regarding germination and seedling environments.

Results and Discussion

Climatological Data

Precipitation and maximum-minimum temperature data for representative weather stations in central and west-central New Mexico were evaluated. Due to the great variability of summer rainstorms from one site to another and, to a lesser degree, winter snowstorms, these data were evaluated for trends rather than actual quantitative values. Before discussing the specific implications of the climatological factors to the principal species, several generalizations are warranted.

January through May of 1967 was a period of drought with generally higher temperatures than normal at all stations. The drought was broken in June with abnormally early, general rainstorms. Numerous storms occurred throughout the summer, bringing precipitation far in excess of normal amounts. October and November precipitation was below normal. December precipitation was near normal at all stations except those of western New Mexico, which received a near-record snowstorm. Little or no precipitation fell at any of the stations in January 1968, but from February to April totals were well above normal. June rainfall was very low at all stations. July and August precipitation totals were above normal and September and October totals were below normal. Data were unavailable for the period January to March 1969 but casual observation indicated above average precipitation in the form of snow.

Table 2. Seedling survival (%) of *Eurotia lanata* at the Fish Hatchery-A, Fish Hatchery-B, Watershed-B, and Fort Wingate sites.

		First counting		Second counting		Last counting		
Site	Plot	Date	No. of seedlings	Date	No. of seedlings	Date	No. of seedlings	Survival
Fish Hatchery-A	1	6/14/68	4	8/5/68	1	3/28/69	0	0
	2		8		1		1	13
	3		9		4		2	22
Fish Hatchery-B	1	6/14/68	ca. 300	7/17/68	ca. 200	3/28/69	20	7
	2		50		21		7	14
Watershed-B	1	7/8/68	ca. 50			3/28/69	22	44
	2		20				3	15
	3		27				3	11
Fort Wingate	1	4/12/68	ca. 500	10/23/68	125	3/30/69	75	15
	2		ca. 200		20		10	5
	3		ca. 200		0		0	0
	4		ca. 200		9		5	3

Germination and Survival

Winterfat usually germinates in late winter and early spring (Plummer et al., 1968; Bleak et al., 1965; Strickler, 1956; U.S. Forest Service, 1948; and Hilton, 1941). Springfield (1968a) and Strickler (1956) agree soil moisture at or near field capacity gives maximum germination; nevertheless, Springfield found a fair percentage of the seeds will germinate under high moisture stresses if the temperature is held near 40 F. Pechanec (1964), discussing seedlings of western plants, and Hubbard (1957), discussing seedlings of bitterbrush, stressed adequate soil moisture must be available following germination to assure seedling success. Thus, as a result of the severe winter and spring drought in early 1967, no seedlings were found when this study was begun in June of that year. Germination did occur in late February and early March 1968 during a period of above-normal precipitation. The number of seedlings produced at that time was enormous at all sites. In areas of seed accumulation (ditches, roadsides, etc.) as many as 2,000 to 3,000 seedlings per square meter were produced. Germination conditions were probably near ideal. Seeds even germinated under several inches of snow at the Fish-Hatchery-B site. Seeds were available from the abundant crop produced in 1967 (probably stimulated by above-normal rains that summer) and from carry-over crops of seeds from previous years. Springfield (1968b) found little loss of viability in winterfat seeds up to three years old, but retention of viability varied from year to year depending on environmental conditions during the time the seeds were forming and maturing and on certain undefined physiological characteristics of the seed. Germination of large numbers of seedlings can be a definite ecological advantage. Ferguson and Basile (1967) found production of large numbers of seedlings of bitterbrush greatly increased the probability of successful establishment. This same conclusion is undoubtedly true for winterfat. However, on properly managed ranges the species can advance even under poor germination conditions (Statler, 1967).

Germination occurred on or near the soil (and litter) surface in all microhabitats, even on bare rocks. This observation agrees with the findings of Springfield (1967), Statler (1967), and Riedl et al. (1964) who suggest winterfat should be planted no deeper than 0.25 inches. Initial establishment was successful wherever the seedling radicles were able to penetrate the soil. Seedlings were able to withstand temperatures at least as low as 12 F (Fry, 1969; and Hilton, 1941) and were probably not limited by subfreezing temperatures that occurred in late winter and early spring 1968. Loss of seedlings by frost-heaving was not apparent in 1968, but observations in March 1969 indicated some of the 1968 plants would be lost due to this action. Strickler (1956) and Biswell et al. (1953) have stressed the importance of this factor. Cracks caused by frost-heaving were observed to serve as germination sites.

Seedlings were successful both near and far (at least 250 m) from mature plants, illustrating excellent wind dispersal. As the spring dry season advanced large numbers of seedlings perished, especially those on bare soil. June 1968 was very dry, but apparently the soil contained enough residual moisture to support large numbers of seedlings. Root growth of survivors during dry periods may have been stimulated by moisture stress (Weaver, 1958). By the time July rains started, only seedlings protected by mature plants of winterfat, those in or very near grass clumps, or those in litter were alive. Observations of the survival plots (Table 2) indicated low survival percentages after one year, but actual numbers of seedlings still alive were rather high.

Seed germination and seedling success of winterfat (Table 2), as occurred in 1968, were rare phenomena that depended upon numerous, complex interactions of plant growth habits and environments. Pechanec (1964) states, ". . . good seed years are infrequent. And the association of good seed years with subsequent climatic conditions favorable to germination and survival is even less frequent." Observations indicate 1967 was an excellent seed production year for winterfat, possibly due to the very wet summer. Certainly, summer moisture conditions were favorable during 1968. Thus, Pechanec's requirements for the establishment of new plants seem to have been met.

Early germination, for plants that can survive subfreezing temperatures, permits the seedlings to become established before other plants, especially grasses, commence growth and start using large quantities of soil moisture. Weaver (1958) states some plants have the ability to germinate, put out several sets of leaves, and then cease shoot growth and undergo rapid root elongation. Winterfat has that type of growth habit. The roots of successful seedlings all penetrated below the grass root-level. Most of the initial root elongation was completed before the grasses started rapid summer growth. Some grasses do show spring growth and as Schultz et al. (1955) report, sufficient moisture from spring precipitation must be present in the soil to allow for both grass and shrub seedling growth. Hubbard (1957) also stresses the importance of sufficient soil moisture in the development of bitterbrush seedlings. An interesting paradox, probably relating to soil moisture, is the dependence of seedlings of winterfat upon their harshest competitor, grass. Seedlings develop best in full sunlight, but not on bare soil because the late spring-early summer soil surface temperatures are very likely lethal to the young, tender plants. Low-growing grasses offer a more hospitable microclimate and act as a "living mulch" even though they reduce maximum development of winterfat. This hypothesis is supported by the following observations. Occasionally seedlings of winterfat are found in litter, although litter, except for dead Russianthistle (*Salsola kali* L.), is scarce on Southwestern ranges. These seedlings, in the presence of mulch and the absence of competition from grass, appear more vigorous than seedlings in grass clumps. H. W. Springfield (personal communication), in studies involving blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) range, found seed germination, seedling survival, and vigor of winterfat to be greater on mulched plots than on unmulched plots. He also observed that seedlings seldom are found on bare soil. Thus, it is apparent that seedlings are more vigorous in mulch or litter than in grass. But, since litter is not common, seedling survival is most often dependent on grass ("living mulch").

Vigorous, expanding stands of winterfat were observed on all slopes and parent materials where livestock use was light to negligible. However, best stands were found on gentle slopes and relatively well-drained alluvial substrate. Soil reactions were slightly basic (pH 7.4 to 8.0). Texture and rockiness varied greatly. These results support the findings of workers in Utah who concluded the species is probably restricted only by high salinity, high alkalinity, and by poorly drained soils (Workman and West, 1967; Gates, Stoddart, and Cook, 1956; Strickler, 1956; and Fautin, 1946). Without exception, in these studies, the vigorous, expanding stands of these plants were found on soils exhibiting some signs of erosion or disturbance, e.g., drainage bottoms, arroyo heads or banks, steep slopes, roadsides, rodent mounds, or sites of active sheet erosion. However, none of these sites were so severely eroded or disturbed that substantial vegetation, especially grass, was not present. Increased water availability, together with some protection for seedlings, appear to be the key factors involved in the success of the species on these sites. Fautin (1946) stated winterfat has relatively high water requirements and often occurs on ". . . soils where watercourses spread out over flat areas and where the normal amount of precipitation is augmented by runoff from higher places." In areas of well-developed caliche layers, the more severe types of erosion and disturbance, such as arroyo heads or banks, drainage channels, or rodent holes, disrupt the caliche and allow water to more readily penetrate the subsoil, and also allow greater opportunity for seedling root development. The direct effect of erosion or other disturbances in removing competing plants is probably of secondary importance since the species is quite tolerant to competition.

Big game use of winterfat was not evident in this study, but livestock use was observed on many ranges. Statler (1967), Kinsinger and Strickler (1961), Eckert (1954), and Hutchings and Stewart (1953) discussed livestock use of the species and all agree overgrazing is detrimental to the plants. The relationship of the degree of utilization to vigor of the species is striking.

Range Vegetation Comparison

A vegetation comparison study was made on the Bernalillo Watershed and the adjacent Sandia Indian Reservation to determine the influence of range condition on reproduction of winterfat (Fig. 1). The comparison was made after summer rains had begun but before significant summer growth started. The watershed was closed to livestock use in 1956 and was subjected to extensive land treatment, e.g., terracing, ripping, discing, etc., (Aldon, 1966). The reservation land has been continually overgrazed for many years. The right side of Fig. 1 shows vegetation on the protected watershed side of the boundary fence and the left side shows vegetation on the overgrazed reservation side.

Heavily grazed ranges, e.g., Sandia

Indian Reservation, may be void of plants of winterfat. Lightly grazed ranges may support stable stands and protected ranges, e.g., parts of Bernalillo Watershed, often support rapidly expanding stands. The Fort Wingate site has been protected only since 1966, yet the stand is advancing rapidly. Contrary to the above, some protected ranges support such vigorous stands of grass that winterfat is excluded (Fig. 1). A precise explanation of the excluding factors involved is not known, but several possibilities merit discussion. Potter and Krenetsky (1967) indicated some grasses, especially black grama (*Bouteloua eriopoda* Torr.) can make dramatic increases in cover on protected ranges. Important influences of different growth forms of grass, indeed species of one genus (*Bouteloua*), may be evident at the Bernalillo Watershed. Watershed-B and Watershed Site 1 are similar in site characteristics. Total vegetational cover and total herbaceous cover are similar at both sites; but the sampling plots of Watershed Site 1 (right side of Fig. 1), having mature, seed-producing plants of winterfat nearby, contained no reproduction of the species. The dominant grass at Watershed-B is blue grama (50% relative cover) with sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray) (27%) as subdominant. At Watershed Site 1 black grama (58%) is dominant and sand dropseed (30%) is subdominant. The crown foliage of blue grama is low (0–10 cm) and tufted, and produces very little ground shade. Crown foliage of black grama, in contrast, is tall (30–45 cm) and compact and often produces dense ground shade, possibly limiting winterfat. Another explanation is the possibility that black grama is a better competitor for spring moisture than blue grama, and in this way deprives winterfat of available water. This latter premise is difficult to accept, however, because both grasses appear to be dormant until after summer rains begin. Seedlings of winterfat were not found even during the period of dormancy.

Watershed Site 2 is similar to Watershed Site 1 in vegetational characteristics and also in the exclusion of winterfat. Watershed-A and Watershed Site 3 both contain low-growing, open-crowned grass species and also winterfat reproduction.

Summary

Drought in the winter and spring of 1967 in central and west-central New Mexico limited spring germination and probably killed many seedlings of winterfat. As a result, little recent reproduction was found when the study was begun in June 1967. Above-normal precipitation in the summer of 1967 and the winter of 1967–1968 proved to be beneficial for reproduction.

Winterfat germinated in February and March 1968 in large numbers and at all sites containing parent plants. Large numbers, but a low percentage, of the seedlings that germinated in 1968 had survived at all sites after one year. In typical winterfat habitat, seedlings did not survive the high summer temperatures produced on bare soil; and survival was limited to the shelter of older plants, clumps of low-growing grasses, and litter. Litter was not abundant on most ranges, and grasses offered the "mulch" necessary for seedling success.

Reproducing stands of winterfat were found on all well-drained slopes, parent materials, and soils that were slightly basic in reaction. The best stands were found on gentle slopes of alluvial origin. All sites were eroded or disturbed but supported a substantial vegetative cover, especially grass. It is the greater amount of available moisture resulting from erosion and disturbance, together with some protection offered by low-growing grasses, that favors establishment of winterfat in the sites observed.

The overgrazed Sandia Indian Reservation land with foliage cover reduced to 22–33% contained no winterfat. The protected Bernalillo Watershed range with 50–60% foliage cover dominated by grasses with low, tufted, open-growth habit contained numerous stands of reproducing winterfat. However, two protected ranges with 61 and 62% cover, dominated by grasses with tall, compact growth habits producing dense ground shade, suppressed reproduction of winterfat.

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Soil and Grazing Influences on a Salt-desert Shrub Range in Western Colorado[1]

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Highlight

Responses of vegetation and ground cover to winter grazing by livestock and to exclusion of livestock for 10 years were observed on soils derived from shale, sandstone, and a mixture of shale and sandstone. Although distinct soil-vegetation relationships were evident, changes attributable to grazing were relatively small. Vegetation and other cover on nongrazed range was practically the same at the end as at the beginning of the study. Overall reductions in galleta, shadscale, and snakeweed were attributed to drought, while differential responses of Salina wildrye, Gardner saltbush, Greenes rabbitbrush, and annual plants were ascribed to grazing. Inherently low site capability and subnormal precipitation were believed responsible for the general lack of response of vegetation to exclusion of livestock.

Resumen[3]

Las Influencias del Suelo y Pastoreo Sobre un Matorral Desertico Salitroso en el Estado de Colorado Occidental.

En el estudio se compararon zonas pastoreadas en invierno con exclusiones de diez años de edad. Se concluyó que había poca influencia del pastoreo sobre le vegetación. La composición vegetal dentro de las exclusiones fué la misma al principio y al final del estudio. Hubo una disminución de las especies *Atriplex confertifolia, Hilaria jamesii* y *Gutierrezia sarothrae* por causa de las sequías.

Hubo varias respuestas diferenciales de las especies *Elymus salinus, Atriplex nuttallii, Chrysothamnus greenei* y plantas anuales debido al pastoreo. El autor piensa que la vegetación no mejoró sin pastoreo porque el potencial fué bajo en los suelos y también hubo un bajo promedio de precipitación pluvial.

Plant cover of the salt-desert shrub type in western Colorado is generally sparse, and runoff usually is heavily laden with sediment. Nevertheless, most of the type is grazed by livestock during winter months, and its deteriorated appearance is commonly ascribed to over-grazing.

To learn more about the responsiveness of vegetation and other range and watershed characteristics to grazing and to exclusion of livestock, a study was started on Badger Wash in west-central Colorado in 1953. Findings during the first 5 years of the study have been reported (Lusby et al., 1963). This paper describes and compares responses of vegetation and ground cover on grazed and nongrazed watersheds from 1953 to 1963, and presents other findings pertinent to the ecology of the salt-desert shrub type.

The author is grateful to employees of the Bureau of Land Management who helped obtain field records, and to S. F. Blake, H. D. Harrington, Jane W. Roller, and J. R. Swallen for identifying most plant specimens. The U.S. Geological Survey, Fish and Wildlife Service, and Bureau of Reclamation, in addition to the Bureau of Land Management and U.S. Forest Service, participated in the overall study.

The Study Area and Methods

Badger Wash is located 25 miles northwest of Grand Junction, Colorado, within the salt-desert shrub type at an elevation of 5,000 ft. Included in the drainage are numerous small watersheds carved principally from Mancos shale (Fig. 1). Though generally hilly, the terrain is rolling where sandy outwash from the Mesa Verde formation overrides the shale.

Annual precipitation averages about 8 inches at Fruita, Colorado, the nearest weather station which is 16 miles distant but at similar elevation. Plant growth occurs mainly from March through May. Although summer thunderstorms are common, temperatures frequently reach the mid-nineties, and surface soil moisture quickly evaporates.

Four pairs of watersheds were selected for detailed observation. One member of each pair was fenced in 1953 to exclude livestock, and the other continued to be grazed by sheep and cattle each year from November until mid-May. Watersheds of individual pairs were contiguous and generally similar in size, exposure, and configuration. Individual watersheds ranged in size from 12 to 107 acres, and together comprised 399 acres.

Three principal soils occupied the watersheds (Fig. 2). "Mixed" soil, so-called because it was derived from a mixture of shale and sandstone, accounted for 61% of the acreage. Soil derived from shale accounted for 17%, and that from sandstone for 15%. Although alluvial soil occupied a minor acreage, vegetation on it was not sampled.

The mixed soil, a Persayo silt loam, differs from the shale-derived soil mainly in that flakes of sandstone are prominent on the ground surface and scattered throughout the soil profile. The shale-derived soil is a silty clay loam, and that from sandstone is a Fruita sandy loam. All are highly calcareous.

Badger Wash has been grazed by livestock since about 1880. Subjected to unrestricted grazing prior to 1934, it subsequently has been part of a large range allotment on which specified numbers of sheep

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FIG. 1. Badger Wash is typical of much salt-desert shrub rangeland in western Colorado and eastern Utah.

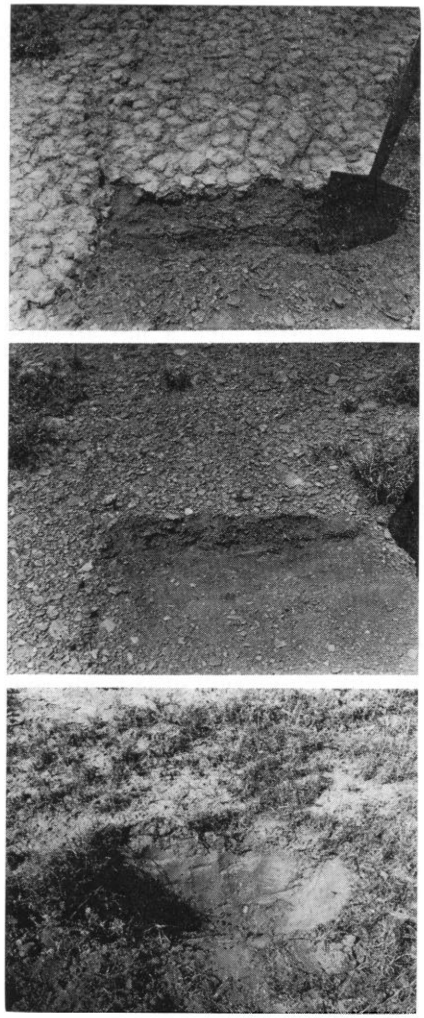

FIG. 2. Soils derived (top to bottom) from shale, a mixture of shale and sandstone, and sandstone. Rock particles on the "mixed" soil are more abundant than usual.

and cattle have been permitted during winter and spring months. Stocking continued to be relatively heavy, however, even during the course of the study.

To provide for measurement of vegetation, 24 line transects 50-ft long were permanently established within each of the eight experimental watersheds in the fall of 1953. Grouped in pairs, the transects were allotted to soil types in proportion to the acreage of each type. Transect locations were determined by random selection, first within soil types then within sampling areas 50-ft square.

Ground cover was measured by the loop-transect method described by Parker (1951). In addition, all shrub crowns intercepted by transects were individually measured and plotted to scale. Unless otherwise indicated, records were obtained during October or November before the beginning of the grazing season. Significance of changes in cover was determined by t-tests or analyses of variance.

Utilization of forage on the four grazed watersheds was determined by ocular estimate at the end of each grazing season from 1956 to 1963. For that purpose a belt transect 2 ft wide was located adjacent to each line transect and divided into segments 10 ft long. Utilization of old (previous season's) and new (current season's) growth of each species in each subplot was estimated separately as a percentage of the weight of herbage produced. Records of the presence of plant species within subplots provided an additional basis for computing plant frequency.

Definition of Terms

Terms used herein to describe ground cover are defined as follows:

Bare soil. Mineral soil exposed over more than half the loop.

Rock. Rock particles at least one-eighth inch in diameter that singly or together occupy more than half the loop.

Litter. Dead organic matter, except leaves still attached to live plants, that occupies more than half the loop.

Plant density index. The number of hits on root crowns of perennial plants in 100 observations.

Shrub crown. Any aerial portion of a shrub observed through the loop.

Ground cover index. An expression of cover computed as 100 minus the number of hits on bare soil and rock not under a shrub crown.

Grazing Use

Unfenced watersheds usually appeared to be closely grazed by the end of the grazing season. However, detailed examination revealed that certain plant species were grazed much more closely than others. Use of old growth of Salina wildrye (*Elymus salinus*),[4] for example, averaged 76% over the 8-year period, 1956–63, as compared to 8% for shadscale (*Atriplex confertifolia*). Use of other common and productive plants—galleta (*Hilaria jamesii*), Greenes rabbitbrush (*Chrysothamnus greenei*), Gardner

[4] Nomenclature follows Harrington (1954).

saltbush (*Atriplex nuttallii*) and broom snakeweed (*Gutierrezia sarothrae*)—averaged 36, 40, 22, and 16%, respectively.

Relatively common but less productive, Indian ricegrass (*Oryzopsis hymenoides*) was grazed 50%. Although use of Torrey ephedra (*Ephedra torreyana*) averaged 61%, winterfat (*Eurotia lanata*) 53%, Sandberg bluegrass (*Poa secunda*) 48%, big sagebrush (*Artemisia tridentata*) 42%, and bud sagebrush (*Artemisia spinescens*) 37%, those plants occurred infrequently and provided little forage. Mat saltbush (*Atriplex corrugata*), horsebrush (*Tetradymia spinosa*) and pricklypear (*Opuntia* spp.) were seldom grazed. Average use of old growth of most perennial forbs ranged from 20% to 35%.

Although new growth of most plants usually was well developed before livestock were removed each spring, it seldom was closely utilized. Most commonly grazed were Salina wildrye, Indian ricegrass, Sandberg bluegrass, segolily (*Calochortus nuttallii*) and ephedra. Use of new growth of those plants averaged 12 to 16%, while that of other perennial plants and annuals rarely exceeded 5%.

Results

Soil Influences

Differences in ground cover on the three principal soils were evident in October 1953 before livestock were excluded from any of the watersheds. On shale-derived soil 79% of the hits by the loop method were on bare soil. This was about one-fourth more than for mixed or sandstone-derived soil. Rock (mainly flakes of sandstone) accounted for 25% of the hits on mixed soil, 2% on shale, and 7% on sandstone. On sandy soil 34% of the hits were classed as litter or moss, as compared to 15% on shale and 17% on mixed soil. Frequency of perennial plants averaged 4% each on shale and mixed, and 6% on sandstone-derived soil. Shale and mixed soils differed mainly in abundance of rock particles, while sandy soil supported more perennial plants and litter.

Table 1. Composition (%) of vegetation on shale, mixed, and sandstone-derived soils in 1953, based on plant density indices.

Kind of plant	Shale	Mixed	Sandstone
Grass	10	45	78
Forb	22	15	7
Shrub	68	40	15
Total	100	100	100

Composition of vegetation on the three soils, as determined from hits on basal crowns of perennial plants (plant density index), was distinctly different (Table 1). Grasses comprised 78% of the plant hits on sandy soil while shrubs accounted for 68% of them on shale-derived soil. Mixed soil supported nearly equal numbers of grasses and shrubs. Though nowhere abundant, forbs were more common on shale then elsewhere.

Soil influences were further expressed through differences in plant species. On shale-derived soil, four species accounted for 83% of the perennial plants: Gardner saltbush 43%; Greenes rabbitbrush 17%; woody aster (*Aster venustus*) 15%; and Salina wildrye 8%. Characteristic of sandy soils, galleta represented 77% and shadscale 8% of the perennial plants encountered there. These plants seldom were observed on shale soil, and those listed for shale seldom occurred on sandy soil. Plants from both groups intermingled on mixed soil. There galleta accounted for 37%; Gardner saltbush 11%; shadscale 10%; and Greenes rabbitbrush 9% of the total. Snakeweed was fairly common on all soils.

Grazing Influences

Ground cover.—All ground cover components decreased on grazed watersheds from 1953 to 1963 (Table 2). Consequently, bare soil increased 12 hits/100. Changes in cover on nongrazed range were small and barely detectable (Fig. 3).

On grazed watersheds, many surface rock particles were covered with soil as the result of livestock trampling. However, summer rainstorms reexposed much of the rock, and by fall the particles were almost as abundant on grazed as on nongrazed range. Seasonal differences in amount of rock exposed on mixed soil within grazed watersheds were in the magnitude of 10 to 14%.

From observations along fencelines it was obvious that trampling by livestock soon destroyed the waffle-like pattern that developed when surface soil dried and contracted. Furthermore, fluffiness of the surface inch of soil, caused by alternate freezing and thawing, was more noticeable, and apparently persisted longer, on nongrazed watersheds. Summer rains also doubtless influenced the duration of those features. Nevertheless, precipitation-runoff relations, initial water absorbing capacity of the soil, and sediment yields were influenced by livestock even though

Table 2. Relative amounts of and changes in cover on grazed and nongrazed range from 1953 to 1963 (in number of hits per hundred observations).

Kind of cover	Grazed range: Amount 1953	Grazed range: Amount 1963	Grazed range: Change 1953–63	Nongrazed range: Amount 1953	Nongrazed range: Amount 1963	Nongrazed range: Change 1953–63
Litter and moss	21	13	−8**	17	18	+1
Perennial plants	4	3	−1**	4	3	−1*
Shrub crown	11	8	−3**	12	13	+1
Ground cover index	29	20	−9**	26	26	0

** $P < .01$
* $P < .05$

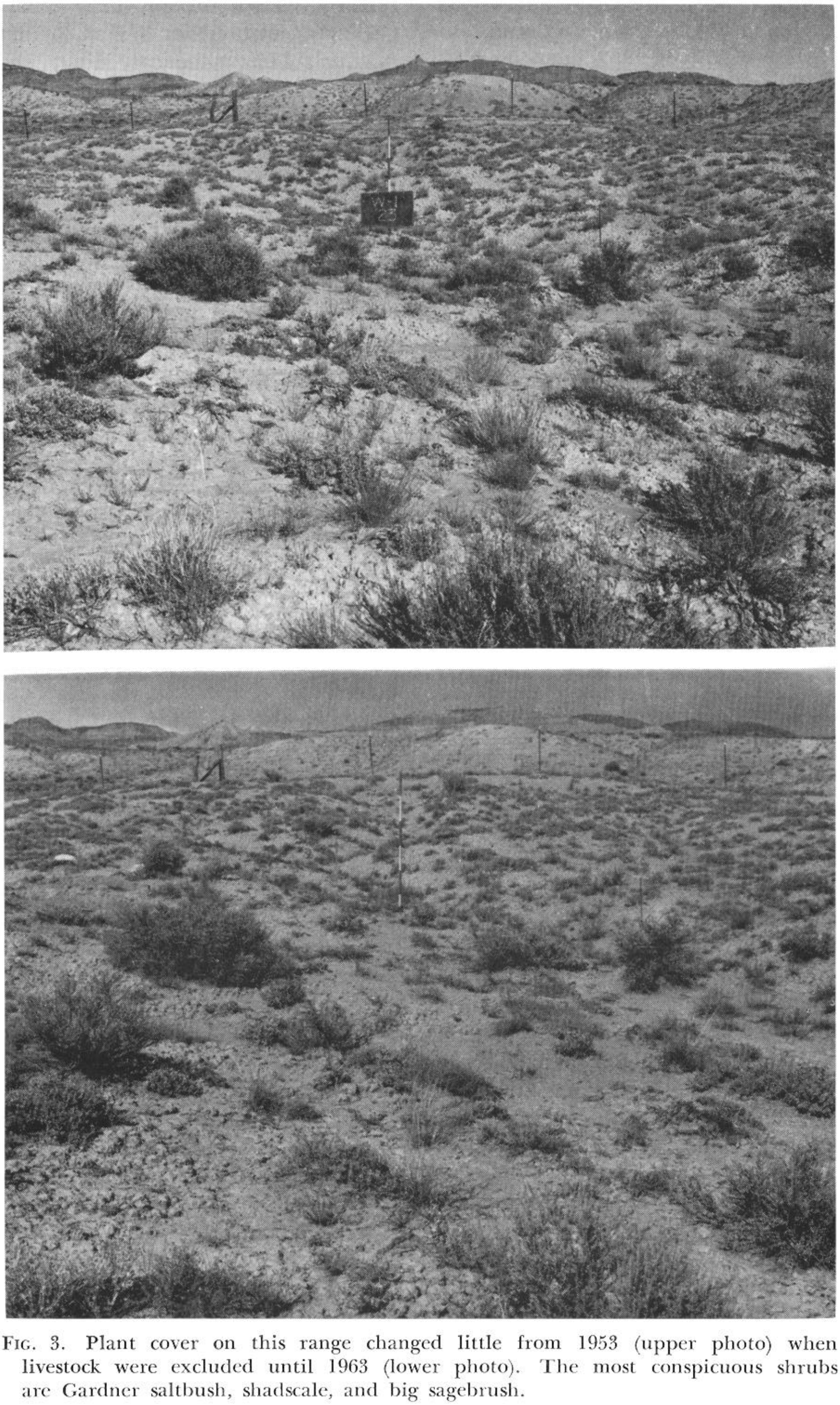

FIG. 3. Plant cover on this range changed little from 1953 (upper photo) when livestock were excluded until 1963 (lower photo). The most conspicuous shrubs are Gardner saltbush, shadscale, and big sagebrush.

changes in ground cover were relatively small (Lusby et al. 1963).

Plant frequency.—Perennial plants decreased 1.3 and 0.7 hits/100, respectively, on grazed and nongrazed ranges over the 10-year period. The reductions, which amounted to 30 and 18% of the frequencies recorded in 1953, generally occurred regardless of grazing or soil type. Shadscale was the only plant to increase appreciably under grazing. On sandy soil within grazed watersheds it increased 0.4 hit/100; elsewhere it decreased. On nongrazed range moderate increases (0.1–0.4 hit/100) occurred in Salina wildrye wherever present; in Indian ricegrass on mixed soil; in woody aster and eriogonums (*Eriogonum* spp.) on shaley soil; and in pricklypear on sandy soil. Grazing caused or contributed to a decline in wildrye, woody aster, Gardner saltbush, and scarlet globemallow (*Sphaeralcea coccinea*) on one or more soil types. Galleta and snakeweed decreased markedly and about equally regardless of grazing. Reductions in galleta averaged 1.0–1.2 hits/100 on sandy soil and about half that on mixed soil.

Records from subplots within belt transects reveal that most annual plants were more abundant on grazed than on nongrazed range in May 1963 (Table 3). Differences among soils also were clearly evident. Especially common on sandy soil within grazed watersheds were cheatgrass brome (*Bromus tectorum*), sixweeks fescue (*Festuca octoflora*), *Gilia polycladon*, stickseed (*Lappula redowskii*), pepperweed (*Lepidium densiflorum*), and woolly Indianwheat (*Plantago purshii*). Most of those species, as well as *Malcolmia africana*, also occurred more frequently on grazed areas underlain with mixed soil. Stickseed and *Eriogonum fusiforme*, the only annuals of note on shaley soil, followed a similar pattern.

Of the more common perennial plants, squirreltail (*Sitanion hystrix*), Indian ricegrass, wild onion (*Allium* sp.), segolily, chimaya (*Cymopteris* spp.), and Greenes rabbitbrush were consistently more frequent on nongrazed range. Unfortunately, records of vegetation on belt transects within nongrazed watersheds were obtained only in 1963; therefore, pretreatment differences are indistinguishable from those caused by grazing.

Shrub canopy.—Shrub crowns covered one-sixth the surface of the experimental watersheds in 1953. By 1963 coverage had declined 32% on grazed and 8% on nongrazed range. Most affected by grazing were Greenes rabbitbrush and Gardner saltbush. Rabbitbrush

Table 3. Frequency (%) of the more common plants within belt-transect subplots in relation to soil origin and watershed treatment, May 1963. Numbers of subplots are shown in parentheses.

	Shale		Mixed		Sandstone	
Species	Grazed (60)	Ungrazed (130)	Grazed (340)	Ungrazed (290)	Grazed (80)	Ungrazed (60)
Grasses						
**Bromus tectorum*	2	3	47	26	90	70
Elymus salinus	17	12	19	23	2	8
**Festuca octoflora*	—	—	7	2	56	40
Hilaria jamesii	7	—	53	42	92	68
Oryzopsis hymenoides	8	8	26	34	4	7
Sitanion hystrix	5	12	15	20	12	42
Forbs						
Allium sp.	—	6	14	19	10	18
Aster venustus	52	57	25	30	4	3
Astragalus missouriensis	—	—	16	11	9	20
Calochortus nuttallii	3	8	11	35	11	25
**Chaenactis stevioides*	—	—	6	—	35	—
Cymopterus spp.	—	5	27	35	10	13
**Descurainia pinnata*	—	—	4	2	6	32
Erigeron pulcherrimus	3	2	15	13	—	5
Erigeron pumilus	—	1	21	21	18	22
Eriogonum microthecum	—	24	2	6	—	—
**Gilia leptomeria*	—	2	16	23	29	72
**Gilia polycladon*	—	—	38	9	49	22
**Lappula redowskii*	37	8	62	35	96	78
**Lepidium densiflorum*	—	—	19	1	56	27
**Malcolmia africana*	5	2	44	18	24	8
Phlox longifolia	10	35	20	28	9	8
**Plantago purshii*	—	—	27	5	90	63
Sphaeralcea coccinea	10	2	26	12	54	52
Shrubs						
Artemisia tridentata	2	1	6	3	5	17
Atriplex confertifolia	3	8	35	39	62	60
Atriplex nuttallii	88	75	34	32	—	—
Chrysothamnus greenei	47	57	32	47	2	10
Gutierrezia sarothrae	13	16	34	32	10	23

* Annual

decreased 64% and saltbush 28% on mixed soil within grazed watersheds. Neither changed more than 9% on nongrazed range.

Only big sagebrush increased appreciably, and its increase was confined to sandy soil within nongrazed watersheds. However, sagebrush comprised only one-fifth of the canopy there even after the increase had occurred.

Although crowns of shadscale and snakeweed were generally less extensive in 1963 than in 1953, their reduction evidently was not caused by grazing. Relevant to nongrazed and grazed areas, shadscale canopy decreased 34 and 41% on sandy soil, 11 and 16% on mixed soil, and not at all on shaley soil. Reductions in snakeweed followed no clear-cut pattern.

Shrub survival.—Of the 1,417 shrub crowns intercepted in 1953, 55% were alive in 1963. Survival averaged 51% on grazed and 58% on nongrazed areas. Under both treatments fewer crowns appeared than disappeared. With respect to grazed and nongrazed watersheds, survival of Gardner saltbush averaged 62 and 72%, and Greenes rabbitbrush 47 and 67%. Grazing had little or no effect on survival of shadscale (63 and 62%), snakeweed (13 and 14%), or other shrubs.

Shadscale survival did vary somewhat with soil type. Of the plants present in 1953, 56% survived on sandy soil and 66% on the finer-textured mixed soil. In 1953 sandy soil supported 325 plants per acre as compared to 86 per acre on mixed soil. Ten years later the numbers had decreased 45 and 26%, respectively. The largest reduction, 58%, occurred on sandy soil within nongrazed watersheds. Survival of other shrubs was not influenced appreciably by soil type.

Age of shrubs.—Persistence of individual shrubs throughout the study, and appearance of others during the study, provided a basis for classifying plants by age group. Some shrubs intercepted after initial records were taken probably were old ones whose crowns had grown across the transect line. They were not distinguished at time of measurement and are considered here to be new plants. Nevertheless, 70 to 80% of the rabbitbrush, shadscale, and Gardner saltbush plants intercepted in 1963 evidently were more than 10 years old. Fewer than one-fifth of the snakeweeds were older than 10 years, and more than half were younger than 6 years.

New plants of shadscale were 1.6 times more numerous on grazed range, and those of rabbitbrush and Gardner saltbush 3.8 and 1.4 times more numerous where livestock were excluded. Young snakeweed plants were relatively scarce, though equally abundant, under both treatments in 1963.

Plant and Ground Cover Relationships

Ground cover under crowns of the four most common shrubs differed considerably in 1953. The most complete cover, and probably the most effective in retarding soil erosion, was that under shadscale. There, on mixed soil, only 13% of the ground surface was bare and 83% was covered with litter or moss. In contrast, nearly half the ground under snakeweed was bare, an additional 30% was occupied by rock particles, and 20% was covered by litter. Cover under Gardner saltbush was similar to but somewhat less than that under shadscale. Under rabbitbrush the cover was slightly denser than under snakeweed.

Perennial plants seldom were present beneath shrub crowns. Only galleta and woody aster were recorded there, although squirreltail and pepperweed (*Lepidium montanum*), were occasionally observed within clumps of shadscale. The fact that perennial plants were less common under than between crowns suggests that shrubs may hinder rather than favor establishment of perennial plants within their immediate vicinity. However, cheatgrass brome and other annuals frequently were more abundant under or near the taller shrubs than elsewhere, particularly on sandy soil.

Perennial grasses and forbs tended to be clustered. On mixed soil, frequencies of perennial plants 6 inches distant from Salina wildrye, galleta, and fleabane (*Erigeron* spp.) averaged 23, 14, and 7%, respectively. For the soil type as a whole it averaged 4%. On sandy soil plant frequency near galleta averaged 13% as compared to 6% for the entire type. The fact that most plants closely associated with one another were the same species suggests that aggregation resulted from spread of parent plants.

Discussion and Conclusions

Vegetation on Badger Wash reflected soil differences more clearly than it did influences of grazing or livestock exclusion. Wherever marked differences in soil on salt-desert shrub ranges are apparent, they should be considered in evaluating site potential and in interpreting responses of vegetation to grazing management.

Failure of ground cover to increase appreciably after livestock were excluded probably was due to low site potential and to drought. Although sandy loam soils evidently were capable of supporting a relatively dense cover, those derived from shale or a mixture of shale and sandstone were generally shallow, highly alkaline, and low in infiltration capacity (Lusby et al. 1963).

That weather was generally unfavorable for plant growth is indicated by the fact that precipitation at Fruita, Colorado was below average in 8 of the 10 years from 1954 to 1963. Except in 1957, when rainfall was unusually abundant, yearly amounts ranged from 4.64 to 8.61 inches and averaged 6.62 inches. Evidently, to remain in balance with available moisture supply, plant cover decreased, even though not grazed.

From studies at the Desert Experimental Range in Utah, Hutchings and Stewart (1953) concluded that moisture was the chief factor limiting plant growth. They noted that productivity of several common plants, including galleta, decreased about equally on grazed and nongrazed range during a 10-year drought. On Badger Wash, reductions in galleta also were similar regardless of grazing.

Evidence from this study further supports observations by Stewart et al. (1940) and Hutchings and Stewart (1953) that drought may cause relatively high mortality of shadscale, especially on sandy soil. The finding that young plants of shadscale were more numerous on grazed than ungrazed watersheds in 1963 indicates that grazing tended to offset such losses. Grazing probably reduces competition from associated plants and thereby enables new plants to become established.

For most perennial plants, conditions evidently were unfavorable for reproduction. Salina wildrye and squirreltail on nongrazed range commonly produced seedstalks but few seedlings. Although Indian ricegrass seedlings were abundant on several occasions, few survived. Insects and rodents, in addition to drought, probably contributed to the losses.

There is little doubt that plant and ground cover on grazed watersheds declined, even though most forage plants were grazed less than recommended by Hutchings (1954). Both grazing and drought evidently contributed to the decline. In 1963 shrub crowns were smaller, perennial grasses less vigorous, ground cover thinner, and annual plants more abundant than on nongrazed range.

Of interest is that Greenes rabbitbrush was readily grazed, and that it decreased substantially under use that averaged 40%. Shantz and Peimeisel (1940) reported that this plant tended to increase under grazing. Broom snakeweed, long recognized as an indicator of overgrazing (Clements, 1920), decreased almost equally on grazed and nongrazed ranges, apparently because of drought.

To summarize briefly, cover on Badger Wash watersheds varied mainly with soil characteristics. It failed to increase following livestock exclusion because of drought and site limitation. Grazing combined with drought resulted in deterioration of cover. Effects of site, weather, and grazing all are important and none should be overlooked when appraising the condition of salt-desert shrub ranges.

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Monthly Variation in the Chemical Composition of Desert Saltbush[1]

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Highlight

An intensive study was undertaken on a southern California range to elucidate the nutritive value of *Atriplex polycarpa* (Torr.) S. Wats. The investigation was designed to show variations in forage values throughout the year and to denote, if any, the correlations between nutritive qualities and the environmental conditions. Forage samples were analyzed for protein, fat, calcium, phosphorus, fiber, total ash, and nitrogen free extract; total digestible nutrients were calculated from digestion coefficients. Although the results showed significant variations in forage value throughout the year, the nutritional requirements of a grazing animal were generally satisfied. Desert saltbush can therefore serve as a dietary supplement and provide important nutritional components such as protein, calcium, phosphorus, and carotenoids when these components are less than adequate in the other available forage.

Desert saltbush (*Atriplex polycarpa* (Torr.) S. Wats.) is an evergreen shrub native to the deserts of southwestern United States. As a perennial it is often the only source of feed available when annual plants are dormant. When dry annual forage is plentiful, cattle graze the dry feed and supplement their diet by browsing desert saltbush. Range forage is sometimes less than adequate in essential nutrients and chemical analysis is necessary to elucidate such deficiencies. As management is intensified, an understanding of forage quality becomes increasingly important.

The chemical composition of a broad class of forage species has been reported by numerous investigators (Cook et al., 1959; Daniel, 1934; Hart et al., 1932; Stoddart, 1941; Weir and Torell, 1959). Conspicuous changes in the chemical composition of grasses and forbs occur with their development (Fraps and Fudge, 1940; Gordon and Sampson, 1939; Patton and Gieseker, 1942; Watkins, 1943). Although the calcium content generally remains relatively constant, protein and phosphorus often decrease with plant maturity. Fiber and nitrogen-free-extract, on the other hand, frequently increase. Other investigators (Cook and Harris, 1950) reported little change in the nutritive value of some desert shrubs through the grazing season. However, in a later study Cook et al., (1959) found that the nutritive value of the animals' diet changed through the year because, with continued grazing, the portion of the plant remaining for further consumption was continually changing. The present investigation was undertaken in an attempt to characterize the forage value of desert saltbush during all seasons of the year and to determine, if any, the correlation of forage values with environmental conditions.

Materials and Methods

Samples were collected from representative plants at a study area in the San Joaquin Valley near McKittrick, California at monthly intervals between November 1966 and September 1967. Four plants were sampled from November to March, then, although only small samples were taken, four other plants were chosen to eliminate the possibility of measuring a harvesting treatment. Each sample was oven dried, separated into leaves, new stems, and old stems, and then ground for analysis. Stems larger than 6 mm (.25 inch) in diameter were not included in the sample.

Fat (ether extract) and fiber determinations were made according to procedures of the Association

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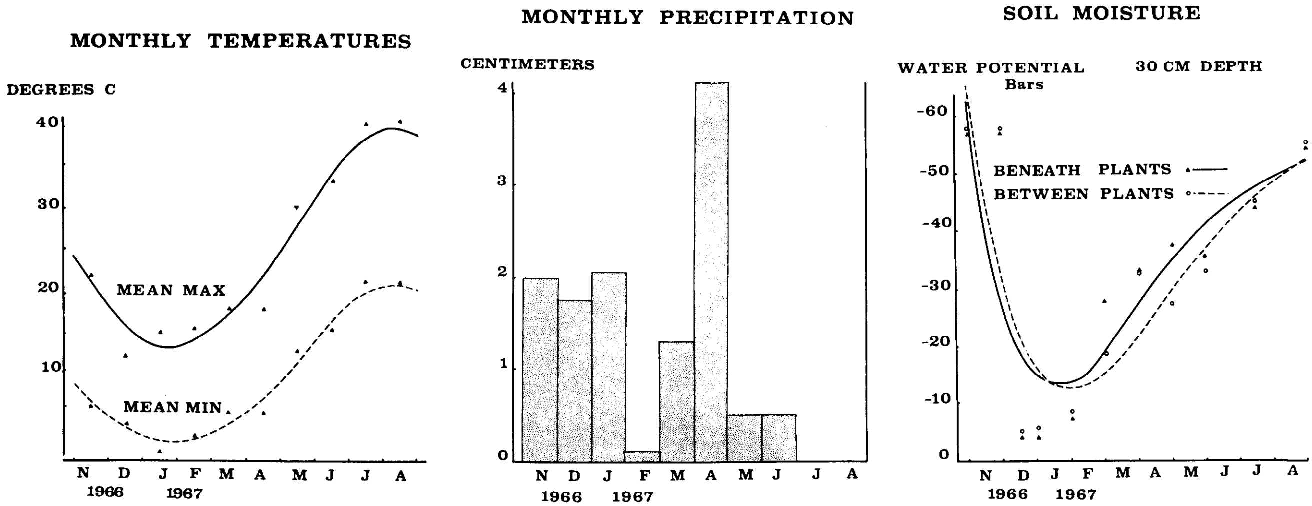

FIG. 1. Environmental conditions at the McKittrick, California study area during the experimental period. Soil moisture was monitored with gypsum blocks.

of Official Agricultural Chemists (1960). Calcium was determined by Na_2EDTA titration after dry-ashing. Following wet digestion, phosphorus was determined colorimetrically by reduction of molybdophorphoric acid complex with stannous chloride. Nitrogen ($N \times 6.25 =$ crude protein) was determined by the micro-Kjeldahl method. Total ash was obtained by muffling the sample at 550 C (1022 F) for two hours. Total digestible nutrients were computed from the digestion coefficients given for saltbushes by Morrison (1959). All results are expressed on a dry weight basis.

Soil moisture conditions were monitored with gypsum blocks concurrently with collection of plant samples. Resistance blocks were placed at two locations with respect to individual plants, directly beneath the crown and at an equal distance between adjacent plants. Replications were placed at depths of 0.3, 0.9, 1.5, 2.25, and 3.0 meters (1, 3, 5, 7.5 and 10 feet) at four sites. Resistance readings were converted to water potential according to McKell et al. (1969). Although values obtained from an extrapolated curve may not be exact in magnitude, trends should be related to the actual changes in water potential. Rainfall and temperature data were taken from the official U.S. Weather Bureau Station at Buttonwillow located near the study area.

Statistical analysis included: (1) analysis of variance and covariance to determine significant differences in chemical composition of plants by collection dates; (2) product moment correlations to compare values for each variable with values of every other variable throughout the year; and (3) weighted polynomial regression to predict curves of values for each component in every plant part throughout the year.

Results and Discussion

Environmental

Air temperatures at the study area ranged from a monthly mean maximum of 40 C (104 F) for August to a mean minimum of –1 C (30 F) in January (Fig. 1). The first frost occurred early in December. Temperatures had risen again by February, sufficient to begin the new season's growth; however, environmental conditions were the most favorable for growth of desert saltbush during May and June.

Precipitation at the study area generally occurs during the winter months, with little if any rainfall in the summer. During the study year, precipitation totaled 12.4 cm (5 inches) (Fig. 1), an amount very near the 11 cm (4.25 inches) mean for the previous 20 years. The low precipitation is reflected in the soil moisture status. Soil moisture increased to the 30 cm depth with the fall rains; however, it decreased steadily throughout the remainder of the season (Fig. 1). Spring rains, which came after the new season's growth of saltbush had begun, were not of sufficient magnitude to alter significantly, the steady decline of soil moisture.

At the deeper levels, soil moisture was always retained at less than –25 bars potential (Fig. 1). At the 30 cm depth, moisture was more positive than –25 bars for fewer than 90 days during the entire year. Apparently, evapotranspiration eliminates most of the precipitation before it penetrates the soil profile to any appreciable depth. The dryness of the soil profile, especially at great depths, may partially explain the relatively shallow root habit of desert saltbush and, in addition, emphasize its drought adaptations.

Forage

Desert saltbush forage from a southern California range showed remarkable variations in the nutritive value in different plant parts at various seasons of the year (Fig. 2).

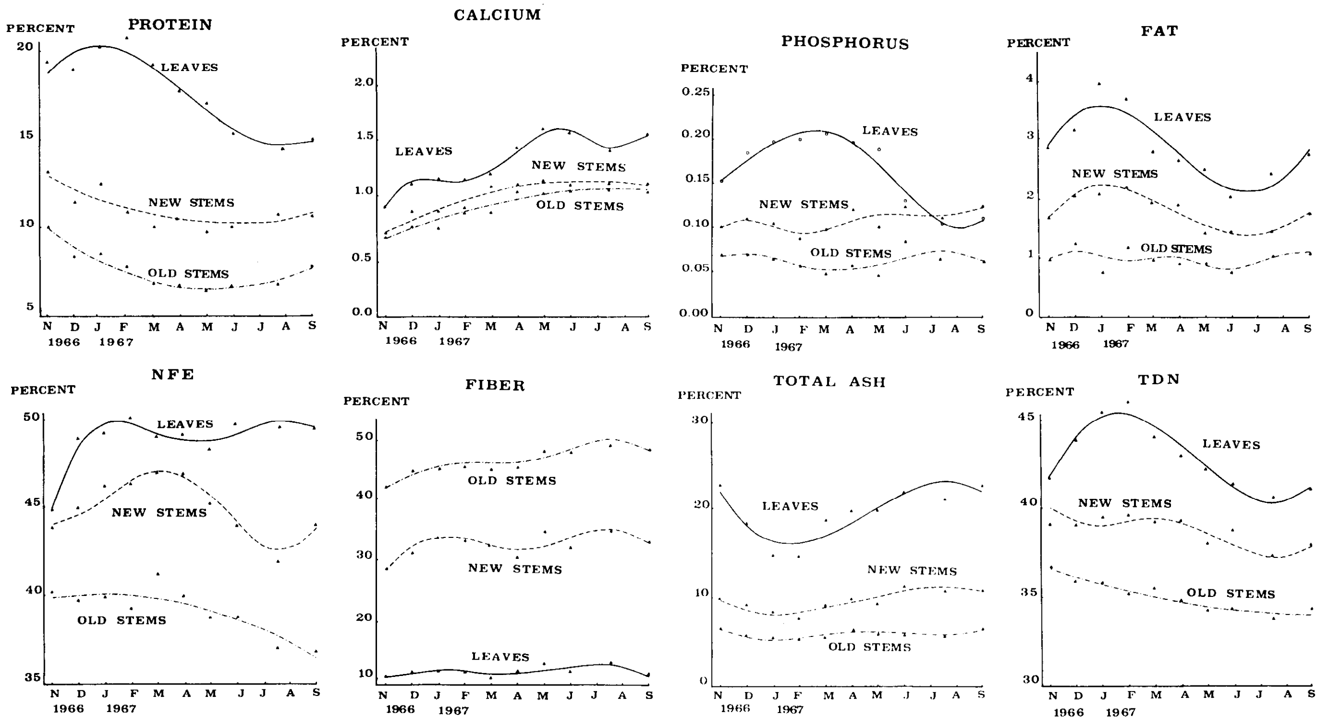

FIG. 2. Chemical constituents of desert saltbush forage collected near McKittrick, California in 1966 and 1967. All percentages are calculated on a dry weight basis.

Leaves.—Leaves were always more nutritious than stems. Leaf samples contained the highest amounts of fat, crude protein, nitrogen free extract, total digestible nutrients, and the least amount of ash, during the cool months of January and February although most of the new growth appeared in May and June (Fig. 2). Values of 2.5–3.5%, 15–20%, and 40–45% were found for fat, protein, and total digestible nutrients, respectively. Such values compare favorably with data given by Morrison (1959) for alfalfa in which he reported 1.9% fat, 15% protein, and 51% total digestible nutrients. Fiber content of the leaves was low compared with the stems and remained relatively constant throughout the year. Calcium varied between 1.0 and 1.5%, which is well in excess of the 0.2 to 0.3% required in a grazing animal's diet (Morrison, 1959). Although the level of phosphorus usually exceeded the required 0.16% (Morrison, 1959), the level dropped below this minimum during late summer. Total ash, found to be predominantly sodium and chloride, varied between 15 and 20% and was highest during late summer. Product moment analyses showed significant positive correlations ($P < 0.01$) between fats, total digestible nutrients, crude protein and phosphorus in the leaves, all of which correlated negatively with total ash.

Stems.—Variations in the chemical content of the stem tissues, throughout the year, were generally much less than for the leaves. Fats and nitrogen free extract in new stems were exceptions; they varied considerably throughout the season and decreased significantly with the new season's growth (Fig. 2). Although calcium in the stems was adequate for animal nutrition, the phosphorus content was not aways sufficient. The calcium:phosphorus ratio exceeded the ideal 2:1 standard; however, the ratio was much less than that reported for *Atriplex confertifolia* and *A. canescens* (Cook et al., 1959). Fats in the new stems were always less than within the leaves and their values followed the same pattern in both plant parts throughout the year. For most other components there was no close correlations ($P > 0.05$) between values in the stems as compared with those in the leaves.

Environment-forage-quality correlations.—Crude protein, phosphorus, fats, and total digestible nutrients in the leaves had significant negative correlations ($P < 0.01$) with the monthly mean maximum air temperatures, as well as the minimum. Soil moisture had no correlation with any of the plant components.

Summary

A study was made of the forage value of desert saltbush in the San Joaquin Valley, California. Plants were sampled concurrently with soil moisture measurements over a 1-year period. The highest forage values were found during the cool, moist season of the year—November through March—even though most of the new growth occurred in May and June. While calcium in the leaves and new stems averaged more than 1%, well in excess of the 0.2 to 0.3% required in an animal's diet, phosphorus averaged

0.14%, slightly less than the 0.16% required. However, the quantity of phosphorus present in the forage was less than adequate only during a short period in the late summer. Values for crude protein, total digestible nutrients, and fat were comparable to those for alfalfa.

The soils supporting desert saltbush were found to be very dry throughout most of the year and generally had a water potential of less than –25 bars. Adaptation to such extreme drought conditions coupled with its acceptable nutritional forage values and salt tolerance (Chatterton and McKell, 1969; Chatterton et al., 1969) makes desert saltbush a valuable range plant in the arid regions of the Southwest. Desert saltbush provides a good source of calcium, phosphorus, and protein as well as carotenoids, especially late in the year when the annual forage has reached maturity and many nutritional components have been lost. The browse value of desert saltbush is often exemplified by its association with unpalatable species. It is often the only shrub present on extensive areas that are too arid or saline for other less-drought-tolerant or less-salt-tolerant forage plants.

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1971 ANNUAL MEETING

February 14–18 Reno, Nevada

See the November 1970 issue of *Journal of Range Management* for tentative program.

Pre-registration and room reservation information was presented in the December 1970 *Rangeman's News*. Room reservations should be made no later than January 31, 1971. Pre-registration is open until February 10, 1971.

Contact the Executive Secretary, 2120 S. Birch St., Denver, Colo. 80222 for additional information.

Response of Medusahead to Paraquat[1]

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Highlight

Medusahead plants from 23 sources were susceptible to paraquat at Davis, California, but resistant to applications of this herbicide at Reno or Stead, Nevada. Differences in response were not due to ecotypic variability among the sources.

Our purpose was to determine if ecotypic variability in medusahead (*Taeniatherum asperum* (Sim.) Nevski) was the cause of differential response of this species to 1,1′-dimethyl-4,4′ bipyridinium ion (paraquat) application in different areas of western United States.

Recent studies have indicated that an application of paraquat is a valuable tool in reducing weed competition to permit the establishment of desirable forage species on rangelands (Evans et al., 1967). This technique has been particularly successful in controlling a number of annual species on the cismontane ranges of California (Kay, 1964, 1968; Kay and Owen, 1970). Paraquat gives excellent control of medusahad in California (Kay, 1964) but does not suppress it effectively at Reno, Nevada (Young et al., 1969). In eastern Oregon, also, paraquat failed to kill medusahead. In general, paraquat kills medusahead west of the mountains in California and Oregon, but has been ineffective east of the Cascades and Sierra Nevada. Other annual grasses are susceptible to paraquat on both sides of the mountains (Evans et al., 1967; Kay and Owen, 1970).

Significant ecotypic variability has been demonstrated among medusahead selections for a number of physiologic characteristics (McKell et al., 1962; Young et al., 1968 a, b; 1970). The demonstration of ecotypic variability suggested that the different responses to paraquat might be inherent.

Methods and Materials

In 1965, we obtained medusahead caryopses from 23 locations in Washington, Oregon, California, Idaho, and Nevada. At the collection sites, five of the sources were known to be susceptible to paraquat, four were known resistant, one had an intermediate response and the other 13 had not been tested for susceptibility to paraquat (Table 1).

The collection locations extend north to south over 700 miles and range in altitude from 50 to 5,170 ft. Mean annual precipitation at the sites ranged from 7 to 43 inches.

The locations are further described by Young et al. (1968 a, b), and are shown on a map by Young et al. (1970).

Caryopses of each selection were planted in three 6-ft rows in four replications of a randomized-block design. Two such gardens were established on October 1 in each of 3 years—1965, 1966, and 1967. The 1965 gardens were at Reno, Nevada. In the other years, the gardens were at Stead, 10 miles north of Reno. Except in 1965, in each successive year, the gardens were planted with the progenies of the previous gardens. In November, 1967 and 1968, gardens were planted at Davis, California. Caryopses used for the three 1967–68 gardens at Davis were a portion of the original collections, and caryopses produced at Stead in 1967 by plants sprayed with paraquat and by unsprayed plants.

The 1968–69 Davis garden consisted of a composite planting of the caryopses of all 23 sources planted in a block.

In July of 1967, we established garden at Stead using caryopses produced at Stead in 1966 and in a separate garden; a portion of the original 1965 collections.

The Stead gardens were irrigated to induce germination. The garden established at Stead in the fall of 1967 did not germinate until the spring of 1968, because of early onset of cold temperatures.

The gardens were sprayed with paraquat at 0.5 lb./acre with the surfactant X-77[2] added at 0.1% per volume. The herbicide was applied with 35 gal/acre of water at 30 psi when the medusahead seedlings reached the two-leaf stage. At Reno-Stead, this varied from early March to mid-April for the October-planted gardens. For the 1967–68 garden at Davis and the summer-planted garden at Stead, the two-leaf stage was reached one month after germination. Portions of the 1968–69 planting at Davis were sprayed at 2-leaf stage, 3-leaf, and 12-leaf stage with 0.25, 0.38, and 0.5 lb./acre of paraquat, respectively.

The degree of susceptibility to paraquat was visually rated on a scale from 1 to 10, with 1 representing no apparent injury and 10 indicating death to all the plants.

Results and Discussion

All the sources of medusahead were resistant to paraquat when grown at Reno or Stead (Table 1). It made no difference whether the plants were grown from the original

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[2] X-77 is a surfactant containing alkylarylpolyoxyethylene glycols, free fatty acids, and isopropanol. Mention of trade name does not constitute endorsement by U.S. Department of Agriculture.

Table 1. Reaction of 23 sources of medusahead to an application of paraquat at 0.5 lb./acre.[a]

Source	Response to paraquat at point of origin[b]	Original seed		Grown at Reno		Parent sprayed with paraquat	
		Davis	Reno	Davis	Reno	Davis	Reno
Adin Airport, Calif.	–	9	1	8	1	8	2
Adin Mountain, Calif.	–	9	1	8	1	8	1
Canby, Calif.	–	8	2	9	1	8	1
Cindercone, Calif.	–	9	1	9	1	8	1
Gazelle, Calif.	I	9	3	9	1	9	2
Hopland, Calif.	S	8	1	9	1	8	1
Likely, Calif.	R	9	1	9	1	9	1
Potter Valley, Calif.	S	7	1	8	1	9	1
Red Bluff, Calif.	S	9	2	8	1	9	2
Vacaville, Calif.	S	9	1	9	2	9	1
Coyote Grade, Idaho	–	8	1	9	2	8	1
Gem #1, Emmett, Idaho	–	7	1	9	1	9	1
Gem #2, Emmett, Idaho	–	9	1	8	2	6	1
Reno, Nevada	R	9	1	9	1	9	1
Verdi, Nevada	R	9	1	9	1	9	1
Corvallis, Ore.	S	9	1	8	1	9	1
Douglas County, Ore.	–	8	1	9	1	9	1
Jackson County, Ore.	–	8	1	8	1	8	1
Ontario, Ore.	R	8	1	8	1	8	1
Richland, Ore.	R	9	2	8	1	8	1
Wheeler County, Ore.	–	8	1	8	1	9	1
Steptoe Butte, Wash.	–	9	1	9	1	7	1

[a] Visually rated on a scale of 1 to 10 with 1 indicating no apparent effect on any plants and 10 indicating death of all plants.
[b] Symbols: R = resistant; S = susceptible; I = intermediate reaction; – no information available.

collections of caryopses or from caryopses grown at Reno or Stead, or whether the parent plants of the caryopses had been sprayed with paraquat.

At Davis, in contrast, all the sources of medusahead were susceptible to paraquat in both years.

At Stead during the summer of 1967, the summer-grown plants sprayed with 0.5 lb./acre of paraquat showed more leaf burn than did winter grown plants, though they largely survived the treatment. These plants over-wintered and were resprayed the next spring without apparent injury. The 1967 common garden at Stead, which did not germinate until the spring of 1968, also survived the paraquat treatment.

Resistance or susceptibility to paraquat at the original collection site showed no apparent relation to response at Reno-Stead or Davis.

There is no evidence that the differences in response to paraquat at the different locations involved ecotypic variability among the various sources. However, a few of the sources were completely killed by the paraquat treatment at Davis. A few plants in many sources retained some green color for a prolonged period. Use of a reduced rate of paraquat might accentuate variability among the sources at Davis, but it would be of little practical significance.

The differences in susceptibility between the cis- and transmontane populations is apparently due to differences in unidentified characteristics of the two environments.

Gazelle, California, approximates a mid-point in environmental conditions between cis- and transmontane California. It is located in a mountain valley at a moderate elevation. At Gazelle, the medusahead population is intermediate in susceptibility to paraquat, but the source from Gazelle is resistant at Reno and susceptible at Davis.

The remarkable point about the variable susceptibility of medusahead to paraquat is that this herbicide has largely contact action with minimal translocation. If paraquat were dependent on translocation in order for it to be phytotoxic, there would be many more chances for environmental interactions.

The practical significance to range managers in the Intermountain area is that they do not have a herbicide for simultaneous spraying and reseeding of medusahead infestations.

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Influence of Rootplowing and Seeding on Composition and Forage Production of Native Grasses[1, 2]

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Highlight

Effects of rootplowing, with or without seeding, on forage production and composition of native grasses were determined on a deep upland range site. Percent composition of stoloniferous species, particularly buffalograss, was reduced initially and after 6 growing seasons by the rootplowing treatments. Frequency counts indicated a reduction of Texas wintergrass on rootplowed plots (seeded and nonseeded) compared to an undisturbed, native check area. This reduction the first growing season was attributed to the competitive effect of sorghum almum introduced in the seeding mixture. Unsuccessful establishment of other seeded grasses (sideoats grama and switchgrass) appeared to be related to poor seedbed preparation, competition from sorghum almum plants, and below normal rainfall immediately after seeding. Rootplowing decreased grass production. After 6 growing seasons, significantly less forage per acre was produced on rootplowed-seeded plots than on nonrootplowed plots. Differences in forage production were related to plant composition and density.

Resumen[4]

La Influencia del Arado Desenraizador Sobre la Produccion y Composicion de los Zacates Nativos

El estudio fué empezado en el año de 1964 en el rancho experimental de Texas en el Municipio de Throckmorton; el diseño incluyó testigo; y se pasó arado para desenraizar sin la siembra y se pasó arado para desenraizar con la siembra. Después de 6 años los dos tratamientos disminuyeron la producción de forraje y composición de zacates deseables.

El zacate sorghum almum (*Sorghum almum*) apareció en la siembra. El arado desenraizador controló el mezquite (*Prosopis glandulosa* var. *glandulosa*).

Rootplowing for control of dense stands of mixed brush, particularly mesquite (*Prosopis glandulosa* var. *glandulosa*), has been highly effective on many areas of Texas rangeland. However, in sections of the state where rainfall is a limiting factor, this practice frequently destroys a high percentage of the desirable perennial grass species and results in invasion of annual grasses and undesirable weeds (Fisher et al., 1959; Jaynes et al., 1968).

This reduction of existing native grasses as a result of rootplowing is apparently associated with soil disturbance and its effect on microclimate. According to Hughes (1966), average maximum soil temperatures were higher and average minimum soil temperatures were lower at the 6-inch depth on rootplowed plots. Minimum soil temperatures were almost 20 F lower than equivalent measurements on nontreated plots. Air movement and evaporation were also greater on the treated area.

Results of Hughes' study showed that rootplowing on a heavy clay soil reduced herbage production of buffalograss and tobosa (*Hilaria mutica*) compared to a nontreated area. Total production was greatest on the rootplowed plot, but forbs and annual grasses were the major components of the vegetative composition.

Powell and Box (1967) concluded that brush control with a minimum of soil disturbance was the most reliable method of improving successional stage and increasing forage production. Results from their investigation revealed that soil disturbance retarded plant succession and caused large fluctuations in yearly forage production.

Since soil disturbance created by rootplowing appears detrimental to certain species of native forages, presumably this disadvantage could be overcome by reseeding in conjunction with root-

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[2] Acknowledgment is made to Swenson Land and Cattle Company for providing the land and livestock utilized in this study and for the support of the Texas Experimental Ranch Committee.

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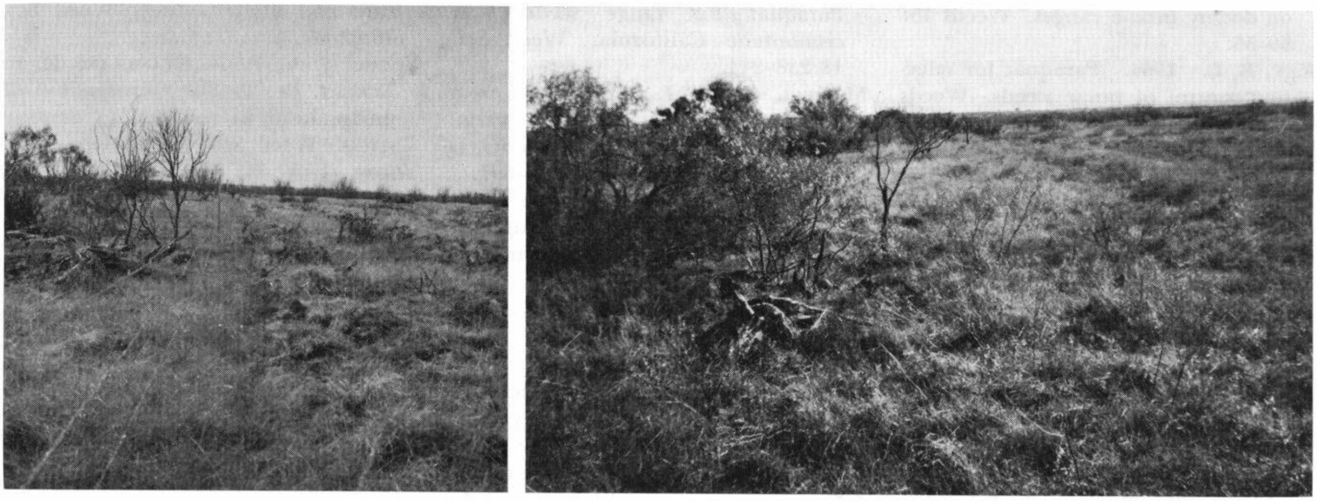

FIG. 1. A view of the study area showing the native check plot adjacent to rootplowed and seeded plots in June, 1964 (left) and in September, 1969, six growing seasons after treatment (right).

plowing. However, results from investigations of this nature are highly erratic. Fisher et al. (1959) reported that good stands of native and introduced grass species were obtained on moderately productive, tobosa–buffalograss type grassland following rootplowing and disking. On the contrary, Jaynes et al. (1968) found that seeding native grasses at the time of rootplowing failed to provide satisfactory stands at several locations. Unsuccessful establishment was attributed to rapid depletion of soil moisture from the loose, open soil created by the rootplow and from severe weed competition.

The objectives of this study were to determine the initial and long term effects of rootplowing, with and without seeding, on forage production and composition of established stands of native grasses.

Study Area and Procedure

The study was conducted on the Texas Experimental Ranch located in Throckmorton County. Although the average annual precipitation (24.83 inches) in this area of the Texas Rolling Plains is somewhat greater than in the western portion, it is considered quite variable (Texas Almanac, 1968). Most of the rainfall occurs during the growing season with May and September the peak months. Annual precipitation was below normal only one year during this study. In 1967, total precipitation was 21.92 inches.

The area used for treatment was a deep upland range site supporting primarily Texas wintergrass and buffalograss with an overstory of moderately dense mesquite (Fig. 1). Since this area had been chained in 1948, most of the mesquite trees were in their secondary growth stage and were of uniform height and canopy cover.

Soil in the experimental plot was classed as Crawford clay with a slope of less than 1%.[5] Characteristically, this soil is a reddish brown, noncalcareous, blocky, heavy clay underlain by limestone at a depth of 20 to 40 inches. This soil is considered highly productive with a high water storage capacity.

In March of 1964, eight adjacent 200 × 25 ft plots were established in a 374 acre reserve pasture on the Experimental Ranch. A preliminary, vegetation survey was made of the area to determine the percent composition and pounds of available forage of existing native grasses. Percent composition and frequency counts were determined by the inclined-point contact method described by Levy and Madden (1933) and available forage was determined by yield from 1.92 ft^2 quadrats. The clipped forage was air-dried, weighed to the nearest tenth of a gram, and converted to pounds per acre by multiplying by 50.

Following the vegetative survey, all 8 plots were plowed to a depth of 12 to 14 inches by a rootplow mounted behind a D-8 Caterpillar tractor. Moisture conditions were considered adequate at the time of plowing.

Four plots were broadcast seeded with an equal mixture of sorghum almum, sideoats grama, and "Caddo" switchgrass to make a total seeding rate of 7 lb./acre and 4 plots were unseeded.

The recommended management procedure following a brush control and seeding treatment of this nature is to defer grazing from the treated area for one or more years during the growing season. In some instances, this results in additional cost to the landowner or operator because of the required reduction in animal units.

Sorghum almum was included in the seeding mixture as a "filler grass" to determine if such a plant could be seeded in conjunction with rootplowing without adversely affecting native stands or the establishment of other seeded species. Sorghum almum has been described as a weak perennial that produces a large volume of forage the first year or two after seeding and then regresses in established stands (Trew, undated). We anticipated that this species might furnish useable forage the first growing season, and provide immediate income to help offset the cost of the treatment.

Immediately after rootplowing and seeding, a fence was constructed to exclude livestock only during 1964. A non-

[5] Soil information obtained from a tentative Soil and Range Classification Guide of Throckmorton County prepared by the U.S.D.A. Soil Conservation Service.

Table 1. Vegetative composition (%) of a grassland community before treatment and after the first and sixth growing seasons following rootplowing with and without seeding.

Species	March, 1964 (Before root plowing)	September, 1964			September, 1969		
		Native Check	Rootplowed		Native Check	Rootplowed	
			Seeded	Nonseeded		Seeded	Nonseeded
Native species							
Texas wintergrass (*Stipa leucotricha*)	67	69	44	69	43	47	41
Buffalograss (*Buchloe dactyloides*)	16	28	8	8	37	14	29
Sideoats grama (*Bouteloua curtipendula*)	0	0	T[1]	0	6	0	7
Miscellaneous grasses	12	0	11	17	8	8	8
Annual grasses	0	2	2	4	3	13	9
Weeds	5	1	6	2	3	3	3
Seeded species							
Sorghum almum (*Sorghum almum*)	–	–	29	–	–	8	2[2]
Sideoats grama (*Bouteloua curtipendula*)	–	–	0	–	–	4	1[2]
Switchgrass (*Panicum virgatum*)	–	–	0	–	–	3	0

[1] Trace.
[2] A small percentage of the seeded species occurred in the nonseeded area due to natural invasion over the six-year period.

rootplowed (native check) plot, established adjacent to the rootplowed area, was not protected from grazing animals.

Stocking rates for the pasture containing the study area were heavy in 1964, 1966, and 1967 at approximately 10 acres per animal unit. Years of lightest utilization were in 1965 and 1969 with 41 and 47 acres per animal unit, respectively. Some deferment was provided during each year except 1964. A 76-day deferment period in 1969 occurred immediately before the final vegetative survey.

Both treated and nontreated areas were evaluated in September of 1964 and 1969 by determining vegetative composition and pounds of available forage by the same techniques previously described. Native and introduced species of sideoats grama were differentiated by their growth forms. The native sideoats grama on the study area was rhizomatous, whereas the seeded species was characteristically the bunch type.

Results and Discussion

A general view of the study area, 6 growing seasons following rootplowing with and without seeding, is shown in Figure 1. Control of mesquite was highly effective, but vegetative surveys revealed initial and long term negetive effects from rootplowing and seeding on composition and reproduction of native grass species.

Vegetative Composition

The initial effect of rootplowing on composition of native grasses is shown in Table 1. The vegetative composition sample of the experimental area revealed that the sod forming or stoloniferous species were less abundant in September of 1964 following rootplowing than they were in March before treatment. Buffalograss was reduced from 16 to 8% on the rootplowed (seeded and nonseeded) areas. Of the miscellaneous grasses, vine mesquite (*Panicum obtusum*) and common curly mesquite (*Hilaria belangeri*) were reduced from 6 and 4% of the original composition, respectively, to 0%.

Texas wintergrass apparently was not affected by rootplowing alone, but rootplowing in conjunction with seeding resulted in a decline of this species. Texas wintergrass is a cool season perennial that normally initiates new growth in September, if moisture conditions are adequate, and matures seed in May. Although conclusive data were not available, it appears that sorghum almum used in the seeding mixture was responsible for the reduction of Texas wintergrass. Sorghum almum contributed 29% to the total vegetative composition in September of 1964; therefore, a sufficient number of plants were present to reduce soil moisture. This may have increased the death loss of Texas wintergrass after rootplowing and limited germination and establishment of new seedlings before the September survey.

There was an increase of less desirable species during the first growing season. Wright threeawn (*Aristida wrightii*) and tall dropseed (*Sporobolus asper*) increased on both rootplowed areas, but sand dropseed (*Sporobolus cryptandrus*) only increased on the nonseeded plots. Annual grasses and weeds were not as abundant the first year after treatment as reported by Fisher et al. (1959) and Jaynes et al. (1968). We assumed that germination of these species was restricted by below normal rainfall during the first 4 months of the 1964 growing season. Also, vegetation was not sampled until September, and the short-lived annual species had already completed their life cycle and disappeared.

Sorghum almum was the only seeded grass in the vegetative composition at the end of the first growing season. The failure to establish sideoats grama and switchgrass was attributed to poor seedbed preparation, competition from the sorghum almum plants, and below normal rainfall during a 4-month period immediately after seeding.

Comparison of vegetative composition on the native check and rootplowed (seeded and nonseeded) plots in September, 1969, revealed long term effects of rootplowing and seeding. The percent composition of Texas wintergrass was approximately the same on all three areas but the percent frequency of Texas wintergrass was 17.7% on the native check compared to 10.4% and 10.7% on the rootplowed, seeded and nonseeded plots, respectively. A reduction in composition of this species on the native check in 1969 compared to 1964 was related to an increase in composition of buffalograss and sideoats grama. However, buffalograss was still greatly reduced on the rootplowed-seeded plots, comprising only 14% of the composition compared to 29 and 37% on the rootplowed-nonseeded and native check areas, respectively. Sideoats grama increased from 0% on the native check and rootplowed-nonseeded plots in 1964 to 6 and 7%, respectively in 1969 but remained at the 0% level on the rootplowed-seeded area. Annual grasses were more abundant on the rootplowed plots, but no differences in percent composition of weeds were observed among treatments.

The three introduced species were present after six growing seasons following rootplowing and seeding. As expected, sorghum almum decreased from 29% in 1964 to 8% in 1969. Sideoats grama and switchgrass accounted for 7% of the total vegetation. Since these two species were not present on the area in 1964, obviously germination and establishment occurred after the first growing season. This would indicate that either moisture conditions were not favorable for germination the year of seeding, or that the seed were partially dormant and required an overwintering period to become viable.

Forage Production

The effect of rootplowing, alone and in combination with seeding, on forage production of native grasses is shown in Figure 2. Although a test of significance was not made for the 1964 data, considerable reduction did occur in pounds of forage produced on the rootplowed (seeded and nonseeded) plots compared to the native check. Airdry forage from the native check plot averaged 1620 lb./acre compared to 1173 and 823 lb./acre for the rootplowed, seeded and nonseeded areas, respectively. These differences probably would have been greater had the untreated area been excluded from grazing during the first year of the study as were the treated plots. This assumption is supported by comparing the pounds of available forage on the experimental area (3122 lb./acre) before rootplowing in March of 1964 to the native check area (1620 lb./acre) in September.

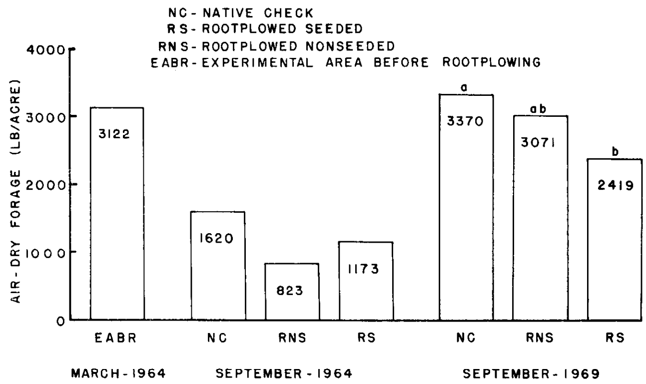

FIG. 2. Initial and long-term effects of rootplowing, with and without seeding, on forage production of native grasses. Values for the 1969 data with different letter superscripts (a,b) are significantly different at $P < .05$.

The difference in production between seeded and nonseeded plots in 1964 was due to the presence of sorghum almum on the seeded area. This species produced 331 pounds of air-dry forage per acre during the first growing season. From observation, this species appeared to produce a larger volume of forage during the second growing season, but plots were not sampled in 1965, therefore, substantiating data were not available.

Production on the rootplowed-seeded plots in 1969 averaged 2419 lb./acre which was significantly ($P < .05$) lower than the 3370 lb./acre produced on the native check. Production on the rootplowed-nonseeded plots was intermediate with an average of 3071 lb./acre. Less forage was produced on the seeded area because sorghum almum had regressed to only 8% of the composition. Possibly this species retarded production of the other grasses by competing for soil moisture and nutrients during the previous years of the study.

Total forage production of each area was related to the percent ground cover as determined by basal density of native grasses. Basal, point-contact readings in 1969 indicated a 41% ground cover on the native check plot compared to 24% on the root plowed (seeded and nonseeded) areas. Greater plant populations of Texas wintergrass, buffalograss, and other stoloniferous species on the native check were responsible for this difference. Although seeded species accounted for 15% of the composition on rootplowed-seeded plots, basal cover was 21% compared to 25% for the rootplowed-nonseeded treatment. Apparently, the seeded species replaced some of the native plants; primarily buffalograss.

Additional studies are needed to determine the feasibility of using sorghum almum or other high producing forage plants in seeding mixtures to help offset the initial cost of rootplowing as a brush control practice. Since rootplowing tends to destroy a certain percentage of native grasses and most rangelands, heavily infested with brush are in poor condition, reestablishment of desirable range plants is a necessity. Therefore, better methods of seedbed preparation and seeding practices in conjunction with rootplowing should be investigated.

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Blue Grama Response to Nitrogen and Clipping Under Two Soil Moisture Levels[1]

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Highlight

Effects of N-fertilization and clipping on production and water use of blue grama were evaluated under two soil moisture levels, field capacity and 1/5 available water. Nitrogen increased shoot production 77% on unclipped plants. Clipping decreased shoot production 287% below the control averaged across N levels. Soil moisture levels produced no differences in yields. Root weights were decreased an average of 253% below the control by clipping. No differences were observed in total water used between fertilized and unfertilized plants but clipping reduced water used by 95%. Unclipped plants fertilized with 80# N/acre used more water than unfertilized unclipped plants. The amount of water required to produce a unit of a shoot was reduced 37% when fertilized. Clipping lowered this water requirement an average of 98%. Nitrogen greatly increased seed stalk numbers and the increase in shoot production due to fertilization came primarily from increased numbers of seed stalks.

Demands on agricultural land for increased production and non-agricultural purposes have necessitated research into methods of improving production on rangelands. The use of fertilizers offers a possibility for increasing rangeland productivity. Blue grama (*Bouteloua gracilis* [H.B.K.] Lag.) is dominant or co-dominant throughout much of the Great Plains and at elevations of 4000 to 6000 feet in the West.

This study was a greenhouse evaluation of blue grama response to nitrogen fertilization under clipping and two soil moisture levels. Investigations were also made during a recovery period to determine possible carry-over effects of the treatments.

Nitrogen fertilization has increased yields on native ranges (Gay and Dwyer, 1965; Smika et al., 1963) and particularly blue grama ranges (Klipple and Retzer, 1959; Lehman et al., 1968; Rogler and Lorenz, 1957). Reproductive capabilities may be enhanced by nitrogen fertilization as shown by increased seed production (Kneebone, 1957) and increased seed stalk numbers. Desirable carry-over effects from nitrogen for as long as three to six years following application have been reported (Kay et al., 1957).

Blue grama responds quickly to both favorable and unfavorable stimuli. Yields may be seriously damaged by frequent clipping (Branson, 1956), although judicious harvesting may stimulate yields of blue grama and prove valuable in the planning of sound management systems (Jameson, 1963). Morphologically, blue grama is resistant to a relatively high level of defoliation because of the inaccessibility of its meristematic growing points (Branson, 1953).

Several studies have shown an increase in water requirement when soil moisture content approaches either extreme (Bennett and Doss, 1963; Briggs and Shantz, 1913). Regardless of the environment, water requirement was reduced when watering was postponed until high soil moisture tensions were reached (Letey and Blank, 1961). Shantz (1927) reported that 312 ± 12 grams of water were required to produce one gram of blue grama under greenhouse conditions. Clipping

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Table 1. Blue grama shoot and root weights (g) under nitrogen fertilization (lb./acre) and clipping.

Clipping treatments	Nitrogen 0	40	80	Mean
Shoot weights				
Clipped[2]	2.89a[1]	3.14a	3.17a	3.07a
Unclipped	7.63b	12.55c	15.46c	11.88b
Mean	5.26a	7.85ab	9.32b	7.48
Root weights				
Clipped[2]	3.94a	3.92a	3.59a	3.82a
Unclipped	9.50b	14.22b	16.79b	13.50b
Mean	6.72a	9.07a	10.19a	8.66

[1]Means with the same small letter are not significantly different within clipping level ($P < .05$).
[2]All differences between clipped and unclipped are significantly different for all fertilizer levels ($P < .05$).

increased water requirement and made moisture stress effects more severe (Briggs and Shantz, 1913). Water requirement of range grasses was decreased by the addition of nitrogen (Lehman et al., 1968; Viets, 1962).

Methods and Procedures

Following a procedure similar to that used by Keller (1954), two-gallon ceramic pots seven inches in diameter and ten inches deep were filled with equal amounts of a thoroughly mixed, air-dry sandy soil. A three-inch by three-inch core of blue grama sod obtained at the Ft. Stanton Cooperative Range Research Station, Ft. Stanton, New Mexico, was inserted into the soil of each pot and allowed to become established at a field capacity water level.

Treatments were applied after a two month establishment period on forty-eight pots selected for their uniformity of stand of blue grama. These treatments were applied in a $3 \times 2 \times 2$ arrangement of three nitrogen levels (0, 40, and 80 lb. N/acre equivalents), two soil moisture levels (field capacity and one-fifth available water), and two clippings levels (no-clip and clipped to a 1½ inch stubble height every ten days), with four replications in a randomized block design. One-fifth available water was determined as 20% of the difference in weight of a given unit of soil at field capacity and at permanent wilting point measured in grams of water. Ammonium sulfate (21% N) was used as the source of nitrogen. Water levels were held constant for the entire 96 day sampling period, after which all treatments were clipped. All pots were then raised to field capacity and allowed to recover for 48 days, after which they were all clipped to determine final production.

Production, water usage, and water requirement were measured throughout the study. Water requirement in this study was based on Viets (1962) definition as the ratio of water absorbed by the plant during the growing season to the weight of dry matter produced by the plant during that time. Upon termination, root weights, leaf lengths, seed stalk length, leaves per seed stalk, seed stalk numbers, and number of inflorescence spikes were measured.

Data were statistically analyzed by the analysis of variance procedures outlined by Steel and Torrie (1960) and significant sources of variation containing more than two means were tested by Duncan's new Multiple Range Test.

Results and Discussion

Shoot Production

Fertilization and clipping both produced differences[2] in above ground dry matter yield of blue grama during the initial portion of this study. Increases in shoot production due to the addition of N on unclipped plants was 64% above the control at the 40 lb. N/acre rate and 103% at the 80 lb. N/acre rate (Table 1). Efficiency of N on unclipped plants, based on grams

[2]All given deviations are significantly different from the control at the .05 probability level unless stated otherwise.

Table 2. Blue grama water use (g) and water requirement (g) under conditions of nitrogen fertilization (lb. N/acre) and clipping.

Clipping treatment	Nitrogen level 0	40	80	Mean
Total water used				
Clipped	6,317a[1]	5,936a	6,153a	6,134a
Unclipped	10,078b	12,058bc	13,647c	11,955b
Mean	8,089a	8,729a	9,532a	8,804
Water requirement[2]				
Clipped	2,222a	1,923a	1,961a	2,041a
Unclipped	1,333b	962c	877d	1,031b
Mean	1,667a	1,282ab	1,219b	1,370

[1]Means with same letter are not significantly different in clipping treatments and nitrogen levels ($P < .05$).
[2]Grams of water required per gram of shoot produced.

Table 3. Blue grama shoot yields (g) following 48 day recovery under prior conditions of nitrogen fertilization (lb./acre) and soil moisture levels.

Moisture	Nitrogen level 0	40	80	Mean
Field capacity	4.31a[1]	5.71ab	6.19b	5.40a
⅕ available water[2]	4.81ab	5.05ab	4.75ab	4.87a
Average	4.56a	5.38b	5.47b	5.14

[1] Means with the same letter are not significantly different within moisture level ($P < .05$).
[2] Maintained at field capacity during recovery period.

of additional grass produced over the control per g of N applied, was 44.3 g at the 40 lb. N/acre rate and 35.3 g at the 80 lb. rate.

Clipping reduced above ground yields by 287% compared to the unclipped treatment averaged across N levels (Table 1). Increased production due to fertilization was not apparent when clipping treatments were applied. It appears that the addition of nitrogen to blue grama which is maintained at a clipping height below two inches will not give increased yields. This is supported by other work (Dwyer, 1969).

There was no difference in yields between the field capacity and one-fifth available water levels, an indication of the ability of blue grama to produce forage under conditions of limited moisture supply.

Root Production

Neither fertilization rates when averaged across clipping levels nor soil moisture levels produced differences in root weights (Table 1). Clipping reduced root weights 253% below those of the unclipped plants, almost the same reduction shown by the shoot production data. Roots, like the shoots, did not respond favorably to additions of N under relatively severe clipping.

Root : Shoot Ratios

Root weights exceeded shoot weights an average of 16% for each treatment, but no differences were shown in root : shoot ratios for any treatment. The response of roots and shoots to the treatments was about equal.

Water Usage

There were no significant differences in total water used between fertilizer rates on clipped plants, but there were differences on unclipped plants (Table 2). Clipping reduced the total water used by 95% compared to unclipped plants averaged across N levels.

Water Requirement

Fertilization rates and clipping levels both produced differences in the water requirement of blue grama (Table 2), but there was no difference between the field capacity and one-fifth available water levels.

Nitrogen applied at 40 and 80 lb. N/acre rates reduced the water requirements below the control when averaged across clipping treatments by 30% and 37%, respectively. It appears that blue grama is more efficient in water use under N fertilization. The absence of response from moisture levels indicates that this increase in water use efficiency due to fertilization may exist within a wide range of available moisture.

Clipping also decreased water requirement to about half of the water required for unclipped grass.

Recovery Study

Shoot production.—Nitrogen fertilization continued to influence shoot production of blue grama during the 48 day recovery period. Results at the end of this period showed that the 40 and 80 lb. N/acre rates increased yields 18 and 20%, respectively, over the control when averaged across moisture levels, however, fertilizer had no influence at the one-fifth available water level (Table 3). This increase amounted to a N efficiency of 7.4 g of grass produced over the control per g of N added at the 40 lb. N/acre rate, and 4.1 gm of grass/g of N at the 80 lb. rate.

Soil moisture levels alone had no influence on yields when carry-over effects were tested.

Blue grama apparently recovered quickly from defoliation since following the 48 day recovery period, there was no carry-over effect from clipping on yields (Table 4).

Water usage.—The carry-over effects of treatments showed that water used at field capacity under 80 lb. N/acre is greater than that used at 0 and 40 lb. of N. Also, water used was less for 80 lb. N than for 0 under one-fifth available water (Table 5).

Those grasses previously maintained at one-fifth available moisture used 17% less water during recovery than those grasses previously maintained at field capacity when averaged across fertilizer levels.

The carry-over effects of clipping continued to reduce water use.

Table 4. Blue grama shoot yields (g) following 48 day recovery under prior conditions of nitrogen fertilization (lb./acre) and clipping.

Treatment	Nitrogen level 0	40	80	Mean
Previously clipped	4.99a[1]	5.35a	4.78a	5.04a
Unclipped	4.14a	5.41ab	6.16b	5.24a
Average	4.56a	5.38ab	5.47b	5.14

[1] Means with the same letter are not significantly different within clipping treatment ($P < .05$).

Table 5. Total water used (g) and water requirement (g) for blue grama during a 48 day recovery period under prior conditions of nitrogen fertilization (lb./acre) and soil moisture levels.

Water measurement	Nitrogen level			
	0	40	80	Mean
Total water used[1]				
Field capacity	4180Ba	4328Ba	4661Bb	4390Ba
⅕ available water[2]	3861Ab	3878Ab	3550Aa	3763Ab
Average	4020Ba	4103Ba	4106Aa	4076
Water requirement[3]				
Field capacity	962Bb	746Aa	741Aa	806Ba
⅕ available water[2]	800Aa	769Aa	763Aa	775Aa
Average	881Bb	757Aa	752Aa	791

[1]Means with same small letter are not significantly different for soil moisture. Those with capital letter are not significantly different for N level ($P < .05$).
[2]Maintained at field capacity during recovery period.
[3]Grams of water required per g shoot produced.

Table 6. Total water used (g) during 48 day recovery period under prior conditions of nitrogen fertilization (lb./acre) and clipping.

Clipping treatment	Nitrogen level			
	0	40	80	Mean
Previously clipped	3886b[1]	4006bc	3472a	3788a
Unclipped	4155a	4200b	4739c	4365b
Average	4020a	4103a	4106a	4076

[1]Means with the same letter are not significantly different within clipping level ($P < .05$).

Blade length.—Based on fertilization and water level treatments without clipping, blade length differences appeared only as a result of water level influence. Leaf lengths under the field capacity water level were 16% greater than those under the one-fifth available water level (Table 7).

No treatments were found to have any measurable effect on seed stalk height.

Leaves per seed stalk.—Fertilization produced no differences in number of leaves per seed stalk, but the field capacity water level averaged an 8% increase in number over the one-fifth available moisture group.

Seed stalk numbers.—Seed stalk numbers were increased considerably over the control as a result of fertilization. The 40 and 80 lb. N/acre rates produced 142% and 263% more seed stalks, respectively, than the control.

Soil moisture levels produced no differences in seed stalk numbers.

Spike numbers.—The number of inflorescence spikes per plant was not affected by water levels, how-

Table 7. Blue grama leaf blade lengths (mm), leaves per seed stalk, seed stalk numbers and spike numbers on unclipped plants under nitrogen fertilization (lb./acre) and soil moisture levels.

Measurement and moisture conditions	Nitrogen level			
	0	40	80	Mean
Leaf blade length				
Field capacity	177.5Aa[1]	184.6Aa	190.6Aa	184.2Ba
⅕ available water	143.7Aa	163.8Aa	169.0Aa	158.8Aa
Average	160.6A	174.2A	179.8A	171.5
No. leaves/seed stalk				
Field capacity	3.45Ba	3.50Ba	3.45Ba	3.47Ba
⅕ available water	3.15Aa	3.38Aa	3.15Aa	3.22Ab
Average	3.30Ba	3.44Aa	3.30Aa	3.34
No. seed stalks/pot				
Field capacity	22.00Aa	55.25Ab	85.50Ac	54.25Ab
⅕ available water	22.75Aa	53.00Ab	77.00Ac	50.92Ab
Average	22.38Aa	54.13Ab	81.25Ac	52.58
Spike numbers				
Field capacity	25.00Aa	68.75Ab	93.75Ac	62.50Ab
⅕ available water	24.50Aa	70.75Ab	93.00Ac	62.75Ab
Average	24.75Aa	69.70Ab	93.37Ac	62.63

[1]Means with the same small letter are not significantly different for that moisture level. Those with capital letters are not significantly different for that N level ($P < .05$).

Those samples previously clipped used 15% less water than those samples not clipped (Table 6).

Water requirement.—Fertilization and clipping both showed differences in water requirement when carry-over effects of the treatments were measured (Tables 5 and 6).

Nitrogen at both the 40 and 80 lb. N/acre rates decreased the water required to produce a gram of shoot below those of the control (Table 6).

Carry-over clipping effects also decreased the water requirement of blue grama.

Source of Increased Production from Fertilized Plants

Significant increases in shoot production from fertilized plants have been shown in this and numerous other studies. This portion of the experiment was an attempt to determine from which plant parts this increased production comes.

ever, the 40 and 80 lb. N/acre fertilization rates produced 181% and 277% more spikes, respectively, than the non-fertilized treatment.

These data imply that in addition to increased forage production, seed stalk and spike numbers due to N-fertilization, the reproductive capabilities of blue grama may be simultaneously improved. The increase in production due to N fertilization comes primarily from increased numbers of reproductive parts, namely flowering culms, or seed stalks and spikes. This, of course, implies more total leaf blades and sheaths since each seed stalk has an average of 3.34 leaves.

Overall the data from this study on blue grama infer that: 1) shoot and root production are both increased about the same order of magnitude with addition of N, 2) no increase in production of shoots and roots is found with N addition when blue grama is clipped to 1½ inch stubble height every 10 days, 3) clipping reduced the total water used nearly 100%, 4) clipping increased the water required per unit of shoot produced about 100% and 5) N fertilization reduced this requirement 37%.

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Blue Grama Vegetation Responds Inconsistently to Cholla Cactus Control[1]

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Highlight

Walkingstick cholla cactus was removed from plots with light (328 plants/acre), moderate (427 plants/acre) and heavy (607 plants/acre) cholla stands, and herbage production was determined on these and corresponding control plots over a four-year period. There were no significant differences between grubbed and ungrubbed for any year on any density class. However, when the data for four years were pooled, there was significantly greater production on the grubbed plots at the light and moderate cholla densities. On the plots with heavy cholla densities, herbaceous production was significantly higher on the ungrubbed plots. Lack of clear-cut response of herbaceous vegetation to cholla removal may be related to differences in early growth and in root distribution of cholla cactus and herbaceous vegetation.

Various species of cholla cactus form a conspicuous component of Southwestern vegetation from California across Arizona, New Mexico, and into Texas and from Colorado in the north to Mexico in the south. In New Mexico, walkingstick cholla (*Opuntia imbricata* (Haw.) DC.) is common in grassland and desert vegetation types occurring on over four million acres (Fig. 1). Livestock operators feel that cholla cactus interferes with livestock movements, reduces grass production, and lowers wool qualities. Consequently, large-scale control programs have been undertaken on many areas. Over 65,000 acres had been controlled in New Mexico by 1966.

Research in Arizona has shown large increases in density of several species of cholla on desert grassland ranges (Glendening, 1952). In New Mexico, density of walkingstick cholla has also increased in the past 50 years (Fraser, 1968). Several studies have reported changes in cholla density following various types of brush-control practices (Humphrey, 1949; Reynolds and Bohning, 1956; Cable, 1967).

However, there has been little research to determine the effects of cholla control on grass production. Ranchers and administrators of control programs need to know what effect cholla control has on herbaceous vegetation before they plan a control program. Consequently, studies to evaluate responses of blue grama vegetation to walkingstick cholla control were initiated on the Fort Stanton Cooperative Range Research Station in the spring of 1966.

Materials and Methods

The Fort Stanton Cooperative Range Research Station is located in the foothills of the Sacramento Mountains in southern Lincoln County, New Mexico. Elevations vary from about 6200 to 7500 feet. The average annual precipitation is about 15½ inches, of which just over 60% falls during June, July, August, and September. Monthly precipitation totals for the study area are presented in Table 1. The vegetation is characterized by pinyon-juniper and oak stands on the shallow, rocky soils and open grassland areas on the deep soils.

The area selected for study was on a low ridge with a slight northeast exposure. There was a pronounced cholla density gradient from the heavy stands on the upper part of the slope to the open stands on the lower part of the slope. The area had not been grazed by domestic livestock for 17 years and was ungrazed during the study period. Plots 75 by 100 feet were established on both sides of the ridge. Cholla plants were counted in each plot. Plots with three density classes of cholla were chosen: 279–378, 410–441, and 505–680 plants per acre. These plots averaged 328 plants/acre on the light stands, 427 on moderate stands, and 607 on heavy stands. There were six plots in each density class; three plots were randomly selected in each density class for complete cholla removal and three were left as ungrubbed control. The experiment was a 2×3 factorial in a completely randomized design with 3 replications. The cholla was removed by hand-grubbing, which disturbed the surrounding vegetation only slightly, if at all. The plots were examined periodically for removal of sprouts and rooted sets.

Herbage production was determined on each plot by hand-clipping all herbaceous growth at ground level from 1×2 ft quadrats. There were 10 such quadrats randomly located in each plot. The quadrats were clipped at the end of the growing season in late September or early October. If a quadrat fell so that a stem or stump of cholla was in the quadrat, the quadrat was moved a predetermined distance and direction before it was clipped. Old growth was discarded and new growth was dried at 70 C before being weighed.

Results

Total herbage production for all treatments and densities for the four years of the study is shown in Table 2. When the data were analyzed separately for each year, the analysis of variance showed no significant differences between treatments or among density classes, nor was the treatment $\times$ density interaction significant. However, when the data for each year were combined, the analysis of variance showed a significant difference among density classes ($P < 0.05$)

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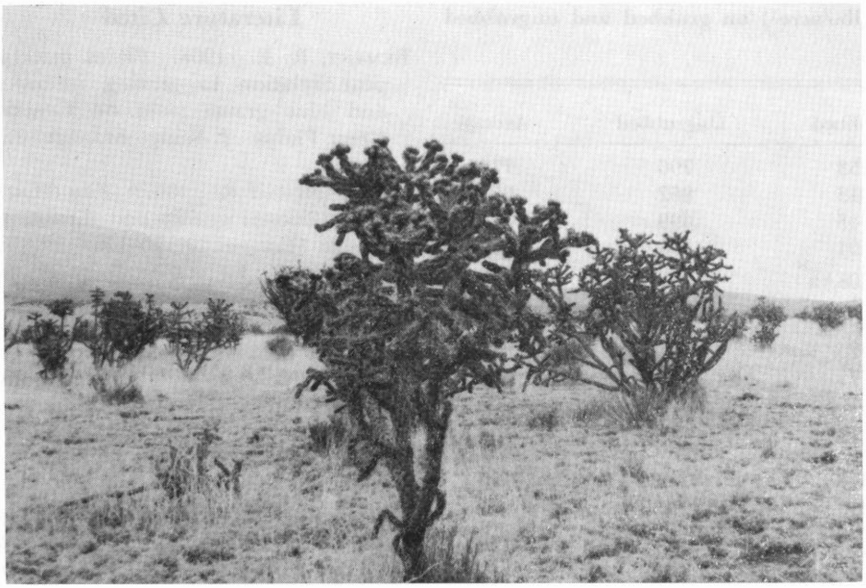

FIG. 1. Large walkingstick cholla cactus plant which is characteristic of grassland vegetation in New Mexico.

and a significant treatment × density interaction ($P < 0.05$).

The significant treatment × density interaction resulted from the differential response of herbaceous vegetation on plots with a heavy cholla stand compared to those with light and moderate stands. Approximately 160 pounds per acre more herbage was produced on the grubbed plots than on the ungrubbed plots of both the light and moderate densities, but 133 pounds more herbage per acre was produced on the ungrubbed plots than on the grubbed plots of the heavy density. These differences were consistent for all years of the study. Consequently, when herbage production was averaged on the grubbed and ungrubbed plots, there was a nonsignificant difference.

There was a nonsignificant difference in herbage production among the different density classes on the grubbed plots. However, the ungrubbed plots with a heavy cholla stand produced significantly more herbage than ungrubbed plots with light and moderate stands of cholla.

Yearly differences in herbage production appears to be related to distribution of precipitation. Highest herbage yields were obtained in 1967, when precipitation was above average in June, July, and August (Table 1). However, differences in precipitation did not change the relative differences between grubbed and ungrubbed plots.

Table 1. Monthly precipitation (inches) totals at the study site.

	Total precipitation			
Month	1966–67	1967–68	1968–69	1969–70
June	1.58	2.00	0.10	0.62
July	2.25	3.39	2.87	3.87
August	0.32	3.76	2.41	2.40
September	6.60	0.43	0.32	2.83
October	0.72	0	0	
November	0.10	0.21	0.41	
December	0	0.85	0.91	
January	Tr	0.45	0.10	
February	0.35	1.12	0.80	
March	0.12	0.50	0.62	
April	0.20	0.10	0.85	
May	0.41	0	1.84	
Totals	12.65	12.81	11.23	

Discussion

The greater production on ungrubbed cholla plots than on grubbed plots at the high density level is difficult to explain on the basis of classical concepts of competition for soil moisture and nutrients. If cholla cactus has detrimental influences on herbaceous vegetation, these influences should be greater at heavy cholla densities than under light and moderate stands. However, data reported here do not support this hypothesis. Herbage production on the ungrubbed plots with heavy cholla densities suggests that cholla may improve microclimatic conditions for herbage production.

The lack of response of herbaceous vegetation to cholla removal at all density classes may be related to differences in growth periods and root distribution between cholla and the herbaceous vegetation. Fraser (1968) has shown that cholla begins and completes its growth earlier than the herbaceous vegetation. Dittmer (1959) found that the root system of walkingstick cholla is rather shallow. Roots of blue grama, the dominant herbaceous species on the site, extend to three feet (Coupland and Johnson, 1965). However, most blue grama root weight is concentrated in the upper 10 inches of soil (Weaver and Darland, 1949). Distribution of blue grama roots on the study area which has not been grazed for 17 years may be different from that on areas of moderate or heavy grazing. Soil moisture studies have revealed close relationships between moisture contained in branches of the cholla plant and soil moisture at the 2-inch level for walkingstick cholla. Cholla branch increase apparently was independent of soil moisture.

Table 2. Average herbage production (lb./acre[1]) on grubbed and ungrubbed plots at Fort Stanton.

Cholla cactus plants/acre	Year	Grubbed	Ungrubbed	Average
328	1966	753	796	775
	1967	1043	862	951
	1968	743	699	721
	1969	691	566	629
	Average	808Aa	731Bb	769d
427	1966	896	867	882
	1967	1025	861	943
	1968	771	608	690
	1969	579	626	603
	Average	818Ca	741Db	780d
607	1966	918	992	955
	1967	813	1048	931
	1968	728	897	813
	1969	744	800	772
	Average	801Ea	934Fc	868e
Average, all densities and years		809G	802G	

[1] Different capital letters indicate significant differences ($P < 0.05$) between means on same line while different small letters indicate significant differences ($P < 0.05$) among means in the same column.

Blue grama herbage weight increase was closely related to soil moisture at 2, 6 and 14-inch depths (Fraser, 1968).

Consequently walkingstick cholla may be drawing on some soil moisture sources which are not utilized heavily by herbaceous species. Bement (1968) found similar conditions for prickly pear cactus on short grass plains in Colorado. His data showed there was no significant difference in herbage production between areas with and without prickly pear cactus.

Evaluation of cholla control does not rest entirely on response of herbaceous vegetation. There is a restriction of utilization of grass plants growing next to the cholla plant and a reluctance of livestock to graze in dense cholla stands (Martin and Tschirley, 1969). However, there are few studies reporting utilization of areas of heavy cholla infestations compared to that on control areas. Other possible benefits of cholla control include easier handling of livestock and higher wool quality on range sheep.

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1971 Dues

Society dues, which include an annual subscription to the *Journal of Range Management* and *Rangeman's News*, are on a calendar year basis.

1971 dues are now past due; delinquent members will be suspended in the near future.

Seasonal Trends in Herbage and Nutrient Production of Important Sandhill Grasses[1]

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Highlight

Aboveground biomass and nutrient production of important grasses were estimated on two range sites in the eastern Colorado sandhills. Apparent seasonal net production of blue grama and western wheatgrass on the sandy plains site was 144 g/m² compared to 90 g/m² for blue grama, prairie sandreed, and needleandthread grasses on the deep-sand range site. Production rates for the grasses studied were 1.8 and 0.8 g/m²/day for the sandy plains and deep-sand range sites, respectively. Herbage biomass decline 28% from the peak standing crop to fall (October 2) on both sites. During the late summer and winter months the biomass declined 50% on the deep-sand site and 35% on the sandy plains site. The sandy plains site produced a larger amount of crude protein than the deep-sand range site. This was accounted for by a larger herbage biomass and a higher percentage of crude protein in grasses grown on the sandy plains site. This more productive site appears to retain more herbage of higher nutritive value throughout the winter than the deep-sand site.

Knowledge of nutrient cycling and energy flow in grassland ecosystems is essential for efficiently utilizing this valuable and renewable resource. Optimal use of the primary producers depends on accurate understanding of the amount and dynamics of herbage biomass and nutrient production. Knowledge of seasonal dynamics of primary producers is the first step in understanding nutrient cycling and energy flow. This paper reports a study of the biomass and nutrient production of important grasses on two range sites in northeastern Colorado.

Water, protein, crude fiber, carbohydrates (nitrogen-free-extract), crude fat, and minerals (ash) are important components of herbage biomass. The magnitudes of these components, their interrelationships, and their availability influence the nutrient flow to the consumers. Generally, moisture, protein, carbohydrates, and many of the minerals are positively correlated to each other; and these factors are negatively correlated to the fibrous and ligneous plant constituents (Sullivan and Garber, 1947; Cook and Harris, 1968). Similarly, nutrient components positively correlated with moisture usually comprise a higher percentage of the plants during early phenological stages. As plants mature and the fibrous and ligneous constituents increase, forage digestibility decreases (Cook and Harris, 1968).

Experimental Area and Procedures

Field work was conducted at the Eastern Colorado Range Station, midway between Akron and Sterling, Colorado. The azonal soils are highly permeable to water, and the topography varies from a dune type with no apparent drainage pattern ("deep-sand" range sites) to a more nearly level topography with defined drainage patterns ("sandy plains" range sites).

The soils on deep-sand range sites are loamy sand or sand at the surface with deep sandy subsoils. Moisture penetration is rapid and deep, and the moisture is readily available to plants. Field capacity is low, but the site is still favorable to tall, deep-rooted species. On the sandy plains sites, the surface soil textures are sandy loam or loamy sands. The subsoil is sandy loam, and the parent material is loamy sand or sand. Moisture intake and storage are fair to good. The sandy plains sites are generally transitional areas between the sandhills and heavier-textured soils.

The primary grasses on the deep-sand range site are prairie sandreed (*Calamovilfa longifolia* Hack.),[3] blue grama (*Bouteloua gracilis* Lag.), and needleandthread (*Stipa comata* L.), a cool-season species. The two warm-season grasses, prairie sandreed and blue grama, grow in close mixture in certain areas; and in other areas they grow in separate patches. The sandy plains range site favors blue grama and a cool season grass, western wheatgrass (*Agropyron smithii* Gaertn.), to the exclusion of prairie sandreed (Lovell, 1960).

Northeastern Colorado's climate is semi-arid, with a mean annual precipitation of 38 cm (15 inches). Most of this comes as rain during the frost-free period, about May 20 to October 20. During this study 26.7 cm (10.5 inches) of rain and 6.6 cm (2.6 inches) of snow occurred.

Two half-acre exclosures were established, with one located on a deep-sand range site and one on a sandy plains range site. Prior treatment for both exclosures consisted of summer and winter grazing at about 22 acres per animal unit month for the previous five years. This was a light to moderate stocking rate during most years, and the range condition on both sites was good and improving (Eastern Colorado Range Station, unpublished data). In each exclosure 15 groups of randomly selected plots (50 plots per group) were assigned sampling dates. Plot size was $.49 \times .91$ m

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[3] Botanical nomenclature follows Harrington (1954).

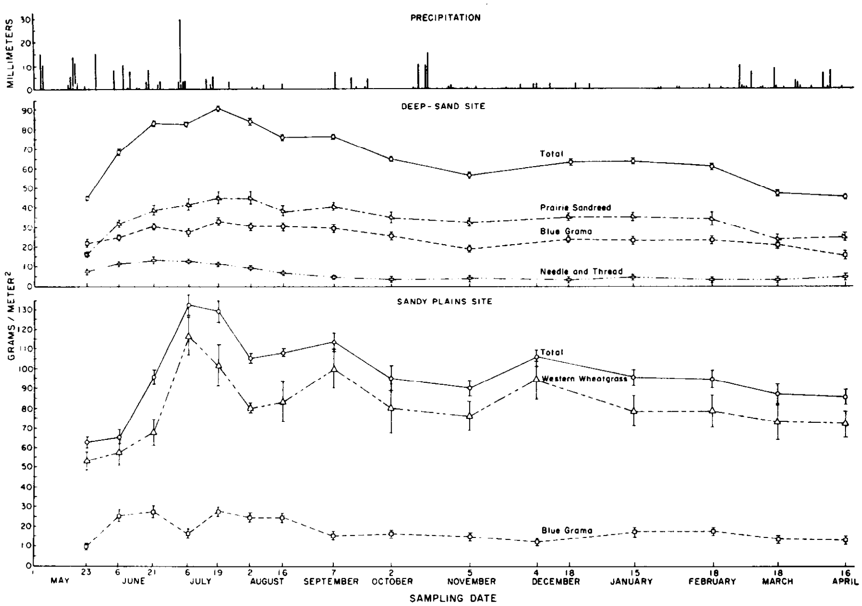

FIG. 1. Seasonal standing crop dynamics of important grasses on two range sites in northeastern Colorado, May 1, 1960 to April 16, 1961.

(1.6 × 3 feet). Clippings were made to near ground level on 15 dates, biweekly May through August, 1960, and monthly September 1960 through April 1961. The preceding year's growth, distinguished by its weathered and faded appearance, was discarded from the sample. Only the important grasses on each site were separated from each sample plot and weighed. Total herbage biomass was not measured. All data were converted to g/m². Blue grama, prairie sandreed, and needleandthread were the important grasses for the deep-sand range site. Western wheatgrass and blue grama were the important grasses on the sandy plains range site.

One composite grass sample for each species at each date was ground through a 1 mm screen and analysed for crude protein (N × 6.25), ether extract, ash, and crude fiber by Industrial Laboratories Company, Denver, Colorado. Nitrogen-free-extract was calculated by difference.

Results and Discussion

Net Primary Production

Deep-sand range site.

The primary grasses on this site reached a peak standing crop of about 90 g/m² in mid-July, 1960 (Fig. 1).[4] This represents an apparent net primary production rate of about 0.8 g/m²/day for these species on this site for the growing period from May 23, the date of first sampling, to July 19. Rates for prairie sandreed and blue grama were about 0.5 and 0.2 g/m²/day, respectively. Needleandthread, a cool-season grass, reached peak standing crop about June 21, a month earlier than the warm-season species. The apparent net primary production rate for this species was about 0.2 g/m²/day up to June 21.

After the standing crop of these three grasses peaked in mid-July, herbage biomass declined, with only minor fluctuations, through March, 1961. The standing crop declined 29%, or about 25 g/m², between July 19 and October 2 and an additional decline of 22%, or about 20 g/m², was noted by April 16, 1961. Somewhat favorable moisture and temperature conditions in October produced small increases in blue grama and prairie sandreed, but these two warm-season grasses generally declined. The standing crop of needleandthread, the cool-season grass that reached peak biomass production at an earlier date, declined at a much greater rate. By fall, a decline of about 60% had occurred followed by an additional 12% decline in standing crop through the winter.

Sandy plains range site.

The aboveground standing crop of blue grama and western wheatgrass on this site reached a peak of 132 g/m² in early July (Fig. 1). The individual peak biomass for these species on the sandy plains site totaled about 144 g/m², 28 g/m² for blue grama on June 21 and 116 g/m² for western wheatgrass on July 6. Combined apparent production rate for these grasses was 1.6 g/m²/day between May 23 and July 6. Apparent net primary productivity for western wheatgrass between May 23 and July 6 was about 1.4 g/m²/day. Apparent net primary productivity for blue grama between May 23 and June 21 was approximately 0.6 g/m²/day. These data indicate that the sandy plains range site was more productive than the deep-sand range site for the 1960 growing season. Western wheatgrass was the most productive species studied and also responded more readily to winter moisture than the other species. Western wheatgrass biomass increased at about .6 g/m²/day, while the blue grama decreased in biomass at a rate of about .04 g/m²/day between November 5 and December 4, 1960, following winter precipitation.

On the sandy plains site the total standing crop of blue grama and western wheatgrass declined 28%, about 37 g/m², between July 6 and October 2. An additional decline of 7%, about 10 g/m², occurred between October 2, 1960 and April 16, 1961, making a total loss of 35%.

Compartmental dynamics.

The transfer rate of standing live vegetation to standing dead vegetation and litter compartments was about the same for the deep-sand range site and the sandy plains

[4] To convert to lb./acre multiply g/m² by 8.91 and to convert to kg/hectare multiply g/m² by 10.

Table 1. Seasonal trends (%) of crude protein of grasses on a deep-sand and a sandy plains range site, May, 1960 to April, 1961.

	Deep-sand site				Sandy plains site		
Date	Prairie sand-reed	Blue grama	Needle-and-thread	Avg.	Western wheat-grass	Blue grama	Avg.
1960							
May 23	12.8	10.8	12.4	12.0	13.9	13.2	13.6
June 6	9.2	9.9	9.4	9.5	10.5	9.1	9.8
June 21	7.4	8.0	7.3	7.5	11.2	9.1	10.2
July 6	6.1	7.1	6.8	6.7	9.4	9.1	9.2
July 19	6.4	6.0	7.2	6.5	6.8	8.3	7.6
Aug. 2	5.1	5.6	6.1	5.6	6.7	7.5	7.1
Aug. 16	4.1	5.3	5.8	5.1	6.2	7.8	7.0
Sept. 7	4.0	5.4	5.3	4.9	8.3	7.4	7.8
Oct. 2	3.7	5.6	5.7	5.0	5.5	6.6	6.0
Nov. 5	4.3	4.8	5.7	4.9	6.0	6.2	6.1
Dec. 4	–	–	–	–	5.6	6.9	6.2
Dec. 18	2.9	4.6	4.1	3.9	–	–	–
1961							
Jan. 15	2.7	4.4	4.3	3.8	3.5	6.2	4.8
Feb. 18	3.5	5.3	3.9	4.9	5.3	5.9	5.6
Mar. 18	2.6	4.4	4.4	3.8	4.7	6.1	5.4
Apr. 16	3.2	4.7	4.8	4.2	5.6	6.6	6.1

site. This was measured as the decrease in biomass from peak standing crop to the end of sampling. The rates of disappearance were about .14 g/m^2/day for both sites. Western wheatgrass, on the sandy plains site, had a much sharper initial decline in biomass weight, and thereafter the amount of this species remained at a level higher than the other species (Fig. 1).

In general, the dynamics of the species biomass on these two sites conforms closely to those mentioned in the literature. For example, Wiegert and Evans (1964) estimated the production rates in an *Aristada purpurescens* and *Poa compressa* field in Michigan at 0.38 to 4.43 g/m^2/day through the growing season. The estimates of production and production rates for the deep-sand and the sandy plains sites would be 5 to 20% lower than total production, since only the major grass species were studied, and total herbage biomass was not measured. However, the grasses studied on each site account for approximately 80 to 95% of the total standing crop (Eastern Colorado Range Station, unpublished data).

The sandy plains site had a higher total biomass of grasses studied than the deep-sand site. In addition, a smaller percentage of grass biomass disappeared on the sandy plains site than on the deep-sand site.

Seasonal Trends of Nutrients

Crude protein concentration.

In general, the seasonal trend of the percentages of crude protein followed a typical pattern (Table 1). Protein content of grasses was highest during early growth and lowest when plants were mature. Crude protein varied from a high of 13.9% on May 23 to a low of 2.6% on March 18. Prairie sandreed and western wheatgrass had the greatest decreases in percentages of crude protein. Crude protein content of prairie sandreed decreased from a high of 12.8% to a low of 2.6%. The protein content of western wheatgrass decreased from a high of 13.9% on May 23 to a low of 3.5% on January 15.

The protein content of grasses on the sandy plains site was consistently higher than the protein content of grasses on the deep-sand site. Grasses on the sandy plains site averaged from 0.3% higher crude protein on June 6 to 2.9% higher on September 7 than the average of the deep-sand site grasses. Blue grama, a species common to both sites, averaged about 1.5% higher in crude protein on the

Table 2. The amount of crude protein (g/m^2, air dry basis) of grasses on a deep-sand and a sandy plains range site May 1, 1960 and April 1, 1961.

	Deep-sand site				Sandy plains site		
Date	Prairie sand-reed	Blue grama	Needle-and-thread	Total	Western wheat-grass	Blue grama	Total
1960							
May 23	2.0	2.3	0.9	5.2	7.4	1.3	8.7
June 6	2.8	2.5	1.1	6.4	6.1	2.3	8.4
June 21	2.9	2.5	1.0	6.4	7.6	2.6	10.2
July 6	2.5	2.0	0.9	5.4	11.0	1.5	12.5
July 19	2.9	2.0	0.8	5.7	6.9	2.3	9.2
Aug. 2	2.3	1.7	0.6	4.6	5.4	2.0	7.4
Aug. 16	1.5	1.6	0.4	3.5	5.2	1.9	7.1
Sept. 7	1.6	1.6	0.3	3.5	8.2	1.1	9.3
Oct. 2	1.3	1.4	0.2	2.9	4.4	1.1	5.5
Nov. 5	1.4	0.9	0.3	2.6	4.6	0.9	5.4
Dec. 4	–	–	–	–	5.3	0.8	6.1
Dec. 18	1.1	1.1	0.1	2.3	–	–	–
1961							
Jan. 15	1.0	1.0	0.2	2.2	2.8	1.0	3.8
Feb. 18	1.2	1.2	0.1	2.5	4.2	1.0	5.2
Mar. 18	0.6	0.9	0.2	1.7	3.5	0.8	4.3
Apr. 16	0.8	0.7	0.2	1.7	4.1	0.9	5.0

sandy plains range site compared to the deep-sand site.

Amount of crude protein.

Seasonal trends in the amount of crude protein per unit area did not follow the same trend as percentages of crude protein or that of herbage biomass. Since crude protein production is an interaction of the amount of herbage biomass and percent of protein in the biomass, an intermediate trend exists. Peak quantities of protein occurred in June or early July (Table 2), the amount of crude protein generally decreasing throughout the remainder of the growing season and winter. Western wheatgrass, the exception, showed an increase in both percent crude protein and herbage biomass and, hence, an increase in the amount of crude protein in early September.

The sandy plains site produced more crude protein than the deep-sand range site. The grasses on the deep-sand site produced 5.2 g/m^2 on May 23. This increased to 6.4 g/m^2 on June 21 and then gradually decreased to 1.7 g/m^2 on March 18. The production of crude protein for the sandy plains site was 8.7 g/m^2 on May 23, 12.5 g/m^2 on July 6, and 4.3 g/m^2 on March 18 (Table 2). The greater protein production on the sandy plains site can be attributed to both the greater biomass production and the higher protein percentage in the grasses.

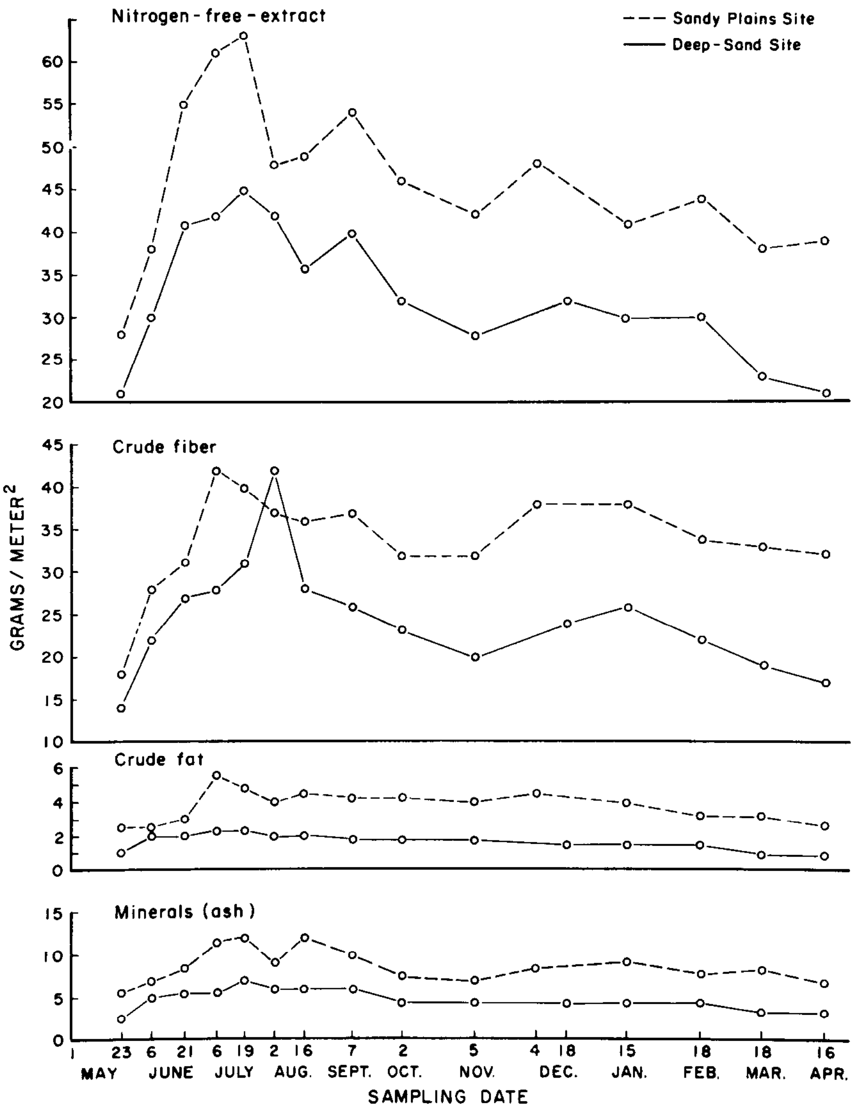

FIG. 2. Seasonal changes in the amounts of nitrogen-free-extract, crude fiber, crude fat, and minerals (ash) on a sandy plains and a deep-sand range site in northeastern Colorado, May 1, 1960 to April 16, 1961.

Amount of nitrogen-free extract.

Nitrogen-free extract (N.F.E.) is an index to the more soluble and easily digested carbohydrates. Since N.F.E. is determined by difference and contains errors inherent to the determination of other proximate components, the values are not exact but are useful for practical consideration (Maynard and Loosli, 1962).

Percentages of N.F.E. were fairly constant throughout the year for most of the grasses studied, varying from about 40 to 50%. Prairie sandreed was the only species that showed an increase in percent N.F.E. with maturity. N.F.E. content of prairie sandreed ranged from 44% in early summer and 51% in late summer and fall. Percent N.F.E. of grasses was usually 2 to 3% lower on the sandy plains site compared to the deep-sand range site.

Seasonal trends in the amount of digestible carbohydrates (N.F.E.) followed the general trend of biomass production. Highest production of N.F.E. occurred during midsummer, July 19, on both sites, 45 and 63 g/m^2 for the deep-sand and sandy plains range sites, respectively (Fig. 2). Thereafter, a gradual, although not steady, decrease in N.F.E. occurred.

The sandy plains range site yielded the most N.F.E. of the two sites at every sampling date. This was due primarily to the larger biomass of western wheatgrass. The N.F.E. production attributed to blue grama on the sandy plains site was approximately 30% less than the N.F.E. production attributed to blue grama on the deep-sand range site. The blue grama biomass from the sandy plains site was consistently lower than that from the deep-sand site (Fig. 1).

Amount of crude fiber.

Crude fiber values are indexes to the less digestible plant carbohydrates (Maynard and Loosli, 1962). The crude fiber production on a site may have an inverse relationship to the digestible nutrients and, therefore, have practical value in the analysis of site productivity. Crude fiber values were consistent for all species and from both sites. All species had about 32% crude fiber during the early summer, 34% during the summer and fall, and about 38% during the winter. The average percentage crude fiber for prairie sandreed, needleandthread, and western wheatgrass was 2 to 4% higher than blue grama during most sampling periods.

Total crude fiber production of grasses on the sandy plains site averaged about 9 g/m² higher than samples from the deep-sand range site (Fig. 2). However, this was not the case for blue grama, since the crude fiber of this species was usually higher on the deep-sand site than on the sandy plains site. Western wheatgrass, accounting for a very high percentage of the dry matter production on the sandy plains site, is somewhat higher in ligneous material and accounts for most of the crude fiber production on this site. Prairie sandreed was second highest producer of crude fiber, and needleandthread yielded the least amount of crude fiber.

Amount of crude fat.

The percentages of crude fat in grasses decreased with the maturity of the grasses on both range sites with the following exception. Needleandthread increased from 3% to 5% crude fat as the season advanced. Western wheatgrass had the highest percentage of crude fat, about 4.5% at peak standing crop and decreased to about 4% during the winter. All other species had from 2.5 to 3% crude fat during early summer and decreased to about 2% during the winter.

Crude fat production on the sandy plains site was about twice as high as the deep-sand site throughout the year (Fig. 2). Again, this was due to the high-producing western wheatgrass. Prairie sandreed produced the second highest crude fat percentage, and needleandthread produced least. Blue grama produced slightly more crude fat on the deep-sand range site than on the sandy plains site.

Amount of ash.

The percentages of ash in grasses did not follow a defined trend. On both sites, the ash content of blue grama increased from about 9 to 11% from the beginning to the end of the sampling period. On the deep-sand site, the ash content of prairie sandreed and needleandthread was about 5 and 7%, respectively, throughout the study period. Western wheatgrass on the sandy plains site had about 9 to 9% ash.

The mineral production, as measured by ashing, was highest on the sandy plains site. The ash content of grasses on the sandy plains site ranged from 2 to 5 g/m² higher than those on the deep sand range site. Western wheatgrass was the largest contributor of ash on the sandy plains site, and blue grama was the largest contributor to ash production on the deep-sand site.

Management Implications

The main advantages of the sandy plains site over the deep-sand site are three-fold: (1) larger biomass of the primary grasses produced, (2) slightly higher protein percentages in grasses, especially during the fall, and (3) greater quantities of crude protein, nitrogen-free extract, crude fiber, crude fat, and ash. Hence, the sandy plains range site would be more favorable for late summer, fall, and winter grazing than the deep-sand site. The forage on the sandy plains site would more nearly approach the nutritional requirements of grazing animals and cattle grazing this site would require less supplementation than those grazing the deep-sand range site.

The loss on both sites of about one-third of the biomass by early October in the absence of grazing by livestock must be taken into account when pastures are reserved for fall or winter usage. The nutrient loss on a unit-area basis is even greater than the biomass loss, inasmuch as the amount of nitrogen and N.F.E. decreased more than 50% by early October.

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Seasonal Variations of the In Vitro Dry-Matter Digestibility of Three Sandhill Grasses[1]

D. F. BURZLAFF

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Highlight

Investigation of the seasonal variation of in vitro dry-matter digestibility of forage of three range grasses was completed. The in vitro dry-matter digestibility declined in all grasses with advance in maturity. Crude protein content declined with advance in maturity and was more highly correlated with dry-matter digestibility than was lignin. Predicted digestibility based on Van Soest's summative equations seemed unrealistically high for forage collections made in late season. No consistent or significant variations in cell-wall constituents or acid-detergent fiber were measured.

The chemical composition of range forage plants has been studied by numerous investigators. These studies have resulted in many publications relating to the proportionate amount of nitrogen, crude fiber, nitrogen-free extract, carotene and of one or more of the mineral components of the forage (Clark and Tisdale, 1945; Cook, Stoddart and Harris, 1956; McCall, 1932; Watkins and Repp, 1964; Beath and Hamilton, 1952).

The real value of a range plant in providing nutriments for livestock lies in two factors—(1) the amount of the forage that an animal will consume on a free-choice basis and (2) the amount of digestible dry matter the animal receives per unit of consumption. Variations in palatability have been documented for various forage plants (U.S. Forest Service, 1953; Forbes and Garrigus, 1950; Davis, 1925). Variations in livestock preference are largely responsible for the classification of range plants into groups according to grazing response as increasers or decreasers. Newell (1968) showed inter- and intra-specific variations in crude protein content and crude fat content of sand bluestem, big bluestem, and switchgrass. He theorized that the variations in crude fat may be closely related to preference patterns of grazing livestock. Hathaway et al. (1945) characterized carotene content of native Nebraska grasses. They reported that sand bluestem of sandhill origin had a higher carotene content than other of the warm-season grasses of eastern Nebraska. Cook and Harris (1968) present extensive data relative to interspecific variations in range forage of the Intermountain Region and the changes that occur with advance in season. They reported also that the nutritional value of a diet reflected animal preference for certain classes of livestock. Hoehne (1966) demonstrated patterns in livestock preference for cattle grazing native ranges in western Nebraska.

Sand bluestem (*Andropogon hallii* Hack.), little bluestem (*Andropogon scoparius* Mich X.), and prairie sandreed (*Calamovilfa longifolia* (Hook.) Scribn.) are three grasses exhibiting variation in apparent livestock preference. These grasses are the major forage resource of certain sandhill ranges and are of concern in programs of revegetating abandoned farmland and depleted rangeland. The study was designed to determine seasonal variations in the nutritive content of these grasses and to determine regression equations for predicting nutritive value of forages.

Procedures

Little bluestem, sand bluestem, and prairie sandreed were established in four replicated plots at the Ft. Robinson Beef Cattle Research Station, Crawford, Nebraska. The stands were obtained by transplanting clonal material from natural grasslands in the vicinity.

Vegetation was collected at various intervals from initiation of growth in the spring of 1963 until one month after killing frost in the fall. New plants were selected for each collection. The material was dried at 63 C in a forced-air oven for 48 hours. The dried material was ground and stored in Mason jars. This material was subjected to laboratory analysis which included determinations for (1) nitrogen content, (2) cell-wall constituents, (3) acid-detergent fiber, (4) acid-detergent lignin, and (5) in vitro dry-matter digestion.

Acid-detergent fiber, cell-wall constituents, and lignin were determined through the use of laboratory techniques outlined by Van Soest (1963) and Van Soest and Wine (1967). Predicted digestibility was calculated from the summative equations of Van Soest et al. (1966). In vitro dry-matter digestibility was obtained through a procedure outlined by Tilley and Terry (1963). Inoculum was obtained from a rumen-fistulated steer on a grass-hay diet. Nitrogen determinations were made in duplicate by the Kjeldahl procedure (Ass. Official Agr. Chem., 1960).

Results and Discussion

Crude Protein Content

Advance in season greatly influenced the crude protein content of all three forages (Fig. 1 and Table 1). The decline in protein content among grasses with advanced maturity was highly significant ($P < .01$). The crude protein content of sand bluestem was higher than that of the other grasses. This superiority of protein content over the other two grasses was maintained at each collection throughout the growing season although the magnitude of difference decreased with maturity. The protein content of little bluestem was the lowest of the three grasses from early July until

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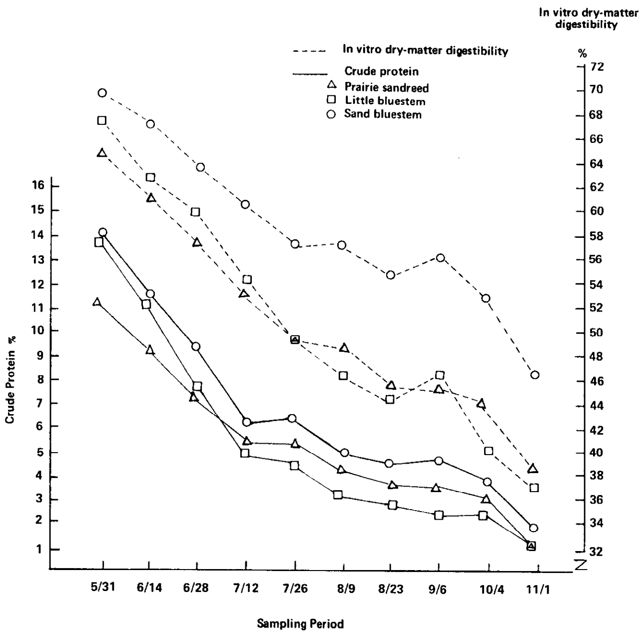

FIG. 1. Variation in the in vitro dry-matter digestibility and crude protein content of forage from 3 range grasses sampled over an extended period.

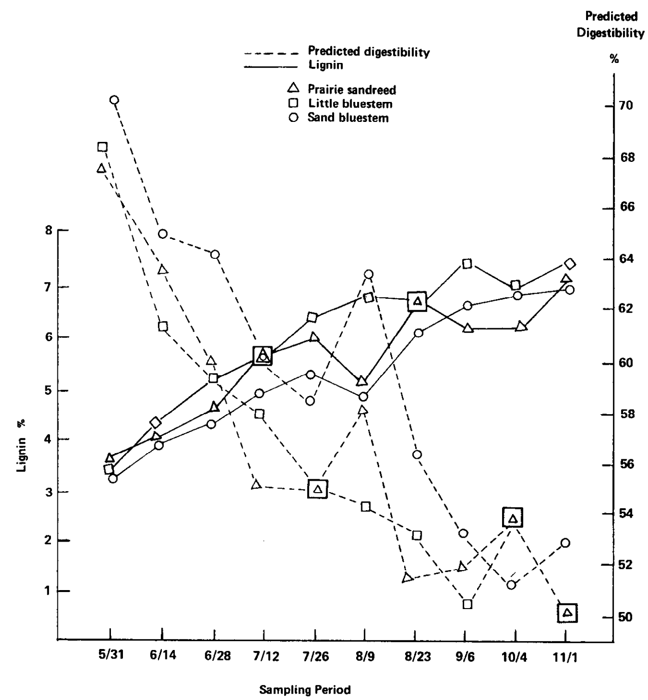

FIG. 2. Variation in predicted digestibility and lignin content of forage from 3 range grasses over an extended period of sampling.

frost when levels of crude protein became similar for all grasses.

Of significance is the rather high correlation (.84) between protein content and in vitro dry-matter digestibility as determined by the artificial rumen (Table 2). This was similar to a correlation coefficient given for the relationship between protein and apparent organic matter digestibility by Forbes and Garrigus (1950). If a consistent relationship between these factors can be established it will be possible to predict the digestibility of range grasses through their crude protein content.

Lignin, Cell-Wall Constituents, and Acid-Detergent Fiber

Lignin content increased significantly with advance in season (Table 1). There were no differences among grasses in this trend to higher levels of lignin in the mature forage (Fig. 2). Hoehne (1966) measured significant negative correlation between lignin content and voluntary intake of range forage. Forbes and Garrigus (1950) reported lignin content of forage was the best measure of its organic matter digestibility. Although the negative relationship was established (Table 2) lignin was not significantly correlated with either in vitro dry-matter digestibility or predicted digestibility. Lignin appears to be of little use as a predictive index for digestibility of range grasses (Table 2).

The percentage of cell-wall constituents seemed to be inconsistently variable with advance in season (Fig. 3). There were no statistically significant patterns to the variations within a particular grass over the sampling period, although differences

Table 1. Mean squares from the analysis of variance for various components of forage of three grasses harvested at various dates in the growing season.

Component	Among dates	Among grasses	Error
Crude protein	81.19 **	13.59 **	0.555
Dry-matter digestibility	504.6 **	539.6 **	39.97
Lignin	8.822**	0.646	1.006
Cell-wall constituents	105.7	349.28 *	89.14
Acid-detergent fiber	65.32	41.26	30.88
Predicted digestibility	290.2 *	155.0	42.82

* Significance at the .05 level.
** Significance at the .01 level.

Table 2. Correlation coefficients and regression equations for selected constituents of range forage.

Constituents	Correlation coefficients	Regression equation	Std. error of reg. coef.
X_1 Y_1	.84	$\hat{Y}_1 = 37.6 + 2.59\ X$	.217
X_1 Y_2	.70	$\hat{Y}_2 = 46.4 + 1.78\ X$	.239
X_2 Y_1	–.31	$\hat{Y}_1 = 66.1 - 2.43\ X$	.952
X_2 Y_2	–.12	$\hat{Y}_2 = 61.1 - .789\ X$	.824

X_1 = crude protein content of forage
X_2 = lignin content of forage
Y_1 = in vitro dry-matter digestibility
Y_2 = predicted dry-matter digestibility

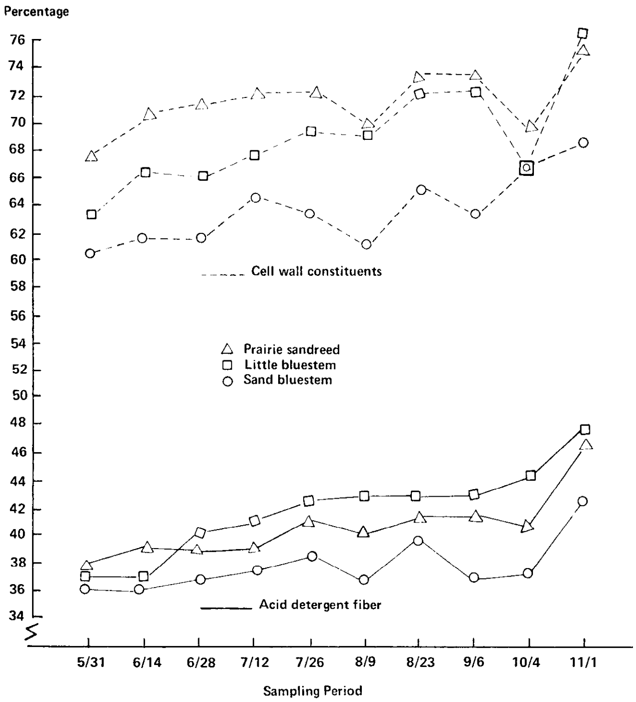

FIG. 3. Trends in the cell-wall constituents and acid-detergent fiber content of forage from 3 range grasses over an extended period of sampling.

among the three grasses were significant ($P < .05$, Table 1). Van Soest (1966) showed a significant relationship between cell-wall constituents and voluntary intake. The consistently lower content of cell-wall constituents demonstrated for sand bluestem (Fig. 3) could, in part, be responsible for the preference exhibited by livestock for this grass.

No significant trends in acid-detergent fiber were measured among the grasses or among sampling dates for a particular grass. Since this fraction represents the lignin plus cellulose portion of the cell-wall constituents it is less closely related to estimates of digestibility than lignin alone.

In Vitro and Predicted Dry-Matter Digestibilities

Estimates of dry-matter digestibility as measured by the artificial rumen or as predicted by Van Soest's (1966) summative equation showed highly significant differences among dates and species (Table 1). Sand bluestem had the highest dry-matter digestibility of any grass with both systems of estimation. Prairie sandreed was intermediate in this respect with little bluestem apparently the least digestible of the three grasses. These trends were consistent for each collection date.

The predicted estimates of digestibility for these grasses did not decline as much in the late sampling dates as did the in vitro determinations of dry-matter digestibility (Figs. 1 and 2). Van Soest (1968) verified the role of silica in digestibility of grasses and indicated that his summative equation had to be corrected to account for this. Unfortunately silica determinations were not made on the forage of these grasses, so such a correction was not possible.

Conclusion

It can be concluded from this study that concentration of crude protein in sand bluestem, little bluestem and prairie sandreed declined with increasing maturity of the forage. The crude protein content of the three grasses exhibited a positive and highly significant correlation with their in vitro dry-matter digestibility.

In vitro dry-matter digestion of the forage of these grasses indicated that sand bluestem was more digestible at all collection dates than little bluestem or prairie sandreed. All three grasses declined in dry-matter digestibility with advance in maturity.

Predicted digestibility using Van Soest's summative equation was less accurate at late stages of maturity. It was theorized this may have been the result of increased silica content. Crude protein was more closely correlated with digestibility than lignin. Although trends existed, no significant of consistent changes in cell-wall constituents or acid-detergent fiber were measured over the sampling period.

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Use of Radiophosphorus and Soil-Block Techniques to Measure Root Development[1]

R. D. PETTIT[2] AND CHESTER C. JAYNES

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Highlight

A radiophosphorus and soil-block technique of root study gave comparable results when studying root growth of switchgrass (*Panicum virgatum*) and sideoats grama (*Bouteloua curtipendula*). Roots of switchgrass penetrated 60 inches laterally from the culms while the sideoats grama root system was much less extensive. The primary advantage of the radioisotope technique of root study is that it allows seasonal root developmental data to be easily collected while soil-block observations are laborious and depict root expanse at only specific times.

A knowledge of the size and extent of grass root systems is an important factor upon which management should be based. This study was initiated to gain a more thorough knowledge of the root systems of "Premier" sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.) and "Grenville" switchgrass (*Panicum virgatum* L.). These species, established 1 year prior to the study, occur in plant communities of the central United States.

Root excavation, a laborious and time-consuming procedure, has been eliminated in much ecological research. With the advent of radioisotopes and particularly with the development of radiophosphorus (^{32}P) in 1935, an entirely new field of study was opened (Hendricks and Dean, 1947). Radioisotopes have thus provided an important tool for basic research in the study of root systems.

^{32}P is particularly well-suited for root-tracer studies (Arnon et al., 1940). It has a half-life of 14.3 days (Desrosier and Rosenstock, 1960) and behaves normally in plant physiological reactions (Kamen, 1957). Under normal soil phosphorus conditions, ^{32}P can still be detected after 6 half lives, a characteristic which makes it ideal for short-term studies.

The objectives of this study were (1) to determine the extent of root development of sideoats grama and switchgrass, and (2) to compare the indirect radioisotope method of root study with the direct soil-block washing technique.

Procedures

"Grenville" switchgrass and "Premier" sideoats grama were planted in 40-inch row spacings on formerly cultivated land of the Texas Tech University Research Farm near Lubbock. Four rows of each species were planted adjacent to each other in 100-foot rows (Fig. 1). The outer row of grass in the 4-row planting was used to detect ^{32}P uptake and provided the sample area for the soil-block technique. A fallow area, 16.7 feet wide and weed free, provided ample room to make soil placements of ^{32}P.

Two replications of randomized complete blocks were established. Nine placement plots were located adjacent to each 100-foot study row. Four identical placement zones, ten inches apart, were located within each plot. A distance of 7.75 feet separated each plot to prevent roots from one area entering an adjacent radioactive plot. Lateral and vertical placement intervals were made 10 to 60 inches from the center of the row of grass clones.

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[1] Cooperative research of Texas Tech and Texas A & M Universities. This paper is part of a manuscript submitted by the senior author to Texas Tech University in partial fulfillment of the requirements for the Master of Science degree. Received January 1, 1970; accepted for publication April 4, 1970.

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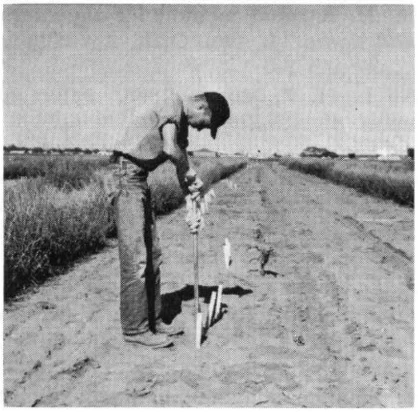

FIG. 1. Field design showing four rows of grass at left and individual placement plots in fallow area.

FIG. 2. Soil-block encased in "steel frame" ready for removal to laboratory for washing. This block weighed in excess of 3400 pounds.

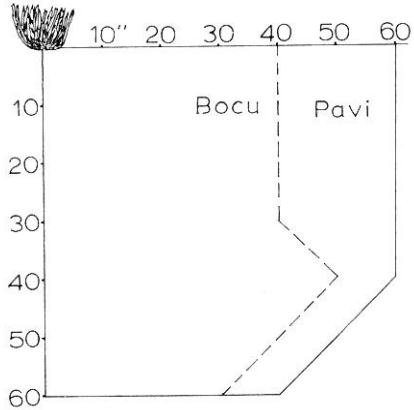

FIG. 3. Expanse of sideoats grama (Bocu) and switchgrass (Pavi) roots as determined by radiophosphorus.

A radiophosphorus technique modified from Mathis, Jaynes, and Thomas (1965) was used. Weak hydrochloric acid containing $^{32}PO_4$ ions was placed in enough distilled water to give a specific activity of 0.00225 mc/ml. Paper cups, each having a capacity of 20 ml were filled with the tracer and then placed on dry ice. When solidified, the paper containers were removed and the radioactive "ice cubes" were transported to the study area.

In each plot four channels had previously been formed with a hydraulically-operated soil-core sampler. One cube of radioactive material was dropped into each channel. Soil was then firmly tamped into the channels.

The presence of ^{32}P in the aerial portion of grass plants, as detected by a portable Geiger-Müller counter, was considered evidence that a part of the root system had entered a placement zone. Plants were monitored every two to seven days throughout the summer until radioactivity could no longer be detected above background radiation.

Pavlychenko's (1937) method of encasing a block of soil in the field was modified for use in this study. A "steel frame" with 76 by 62-inch dimensions was used to encase a block of soil which had been excavated with a trenching machine (Fig. 2). A 30-cubic-foot soil block was taken to the laboratory for removal of the soil from the root system.

Results and Discussion

Isotope Method

Switchgrass roots grew a lateral distance of 60 inches from the culms (Fig. 3). At this lateral distance, roots penetrated to a 40-inch depth. Forty inches from the grass culms, roots were found to a depth of 60 inches.

Six days after ^{32}P was placed in the soil, roots entered a radioactive zone at two 10-inch and one 20-inch lateral placement levels located at vertical depth of 10-inches and 30-inches respectively.

Sideoats grama roots grew in a lateral direction as much as 50 inches from the culms (Fig. 3). At this lateral distance, the maximum depth of root penetration was 40 inches. At a lateral distance of 40 inches, the depth of root penetration was 30 inches. The maximum distance penetrated by roots was 30 inches laterally and 60 inches vertically. One 30-inch and one 10-inch lateral placement, each at a depth of 10 inches, were the first zones to be penetrated by roots as indicated by radiation from aerial tissues.

Extreme care was used during the monitoring process. A lead shield was used to isolate specific culms and plant parts during the monitoring process. Part of the culms emitted radiation while others did not which indicated that specific culms of a grass clone have roots entering different areas of the soil. Apparently very little or no lateral translocation of phosphorus occurs in the crown region of these species. Additionally, those culms located at the back or away from the placement plots were attached to the roots entering the radioactive zones at the lower depths. Culms located towards the placement zones generally contained the beta radiation from the upper 30 inches or less of the radioactive zones. Further research is needed, however, before positive statements can be made concerning translocation and individual root penetration patterns.

Phenological changes in the plant were responsible for causing large variations in radioactivity within a culm. Lower nodal areas emitted more radiation than older leaf tissues. Also during flowering and when seeds began to develop, ^{32}P was concentrated in the inflorescence. This response was expected and is directly related to the role of phosphorus in plant growth and development.

Soil-block Method

Direct observations showed switchgrass roots to be less extensive than was indicated by the

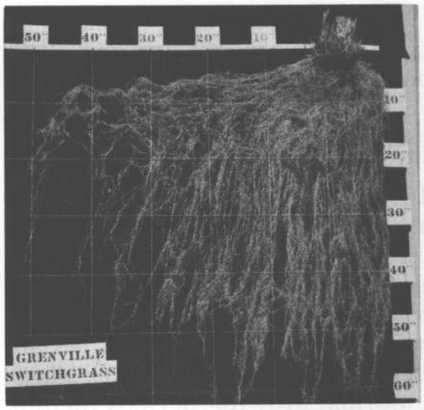

FIG. 4. Exposed root system of switchgrass after soil-block from Fig. 2 was washed.

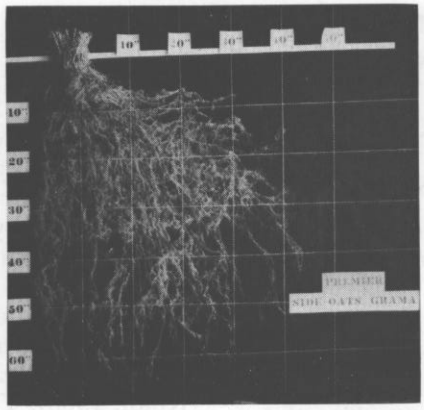

FIG. 5. Sideoats grama root development showing a vertical orientation of roots.

tracer technique. Maximum lateral extension was slightly over 50 inches (Fig. 4). Outward growth from the culms was uniform.

Switchgrass primary and secondary roots were characterized by having a woody-like nature throughout. The tertiary roots and other lower order roots were fragile and thus lost during the washing process.

Sideoats grama roots extended downward 60 inches at a 30-inch lateral distance from the culms (Fig. 5). Few roots were found beyond 30 inches from the culms.

Sideoats grama root diameters were approximately one-half as large as those of switchgrass roots. The roots of sideoats were more vertically orientated than those of switchgrass. These differences are likely due to genetic differences between species as soil moisture levels were similar in all plots. Extra care was necessary in washing the sideoats grama block to avoid loss of roots.

Comparison of Methods

The expanse of switchgrass root systems varied 10 inches between the two methods of study. The soil-block was encased August 1, and on this date, roots had not extended into the 60-inch lateral zone as indicated by the Geiger-Müller counter. All the 60-inch lateral readings were recorded in August; therefore, it is assumed that the roots grew an additional 10 inches after August 1.

Little variation was found between the two methods used in the root study of sideoats grama. Excavation for direct study was not made until August 15, at which time most roots had apparently reached their maximum penetration.

Soil moisture stresses are believed to have played a significant role in determining the results of this study. Available soil moisture was low directly beneath culm areas throughout August. The capillary movement of soil moisture from the fallow area toward the drier soil plus a general growth response of root systems may have caused roots to extend outward abnormally far from the culms.

These two methods of root study are comparable. Direct observation of root systems requires more labor and time than the isotope technique. Possibilities of errors are greater when using the soil-block for at least three reasons: (1) a much smaller area is sampled by the soil-block than by the isotope, (2) a 12-inch wide sample may not include all primary laterals, and (3) variations in sampling areas may increase errors.

The ease of placing radioisotopes into soils with their subsequent uptake by plants makes the isotope technique a preferred method of root study. Greater precaution must be exercised in handling tracer solutions, but results appear to be more accurate in determining root growth over a period of time.

Isotopic tracers can be used on most range lands. The primary limitation would be in placing them at sufficient depths in areas with rocky substrata. Also, the possible occurrence of amorphous soil colloids such as allophane renders ^{32}P unusable since phosphorus fixation is a problem in these soils. The soil-block method requires an abundant water supply, and a winch truck or similar power source is necessary to lift blocks from the soil.

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OVERSEAS OPPORTUNITIES

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Rainfall Pattern and Monthly Forage Yields in Thal Ranges of Pakistan[1]

CH. M. ANWAR KHAN[2]

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Highlight

The multiple correlation and multiple regression between monthly forage yield of dhaman (*Cenchrus ciliaris* Linn.) and the four factors of the amount of monthly rainfall, the number of rainy days in the month, the amount of rainfall during the previous month and the month of the growing period were positive and highly significant (0.01 level). The same multiple relationships for karera (*Elyonurus hirsutus* Vahl.) were significant only if rainfall during the previous month was not included. There were highly significant positive correlation and regression relationships between forage yield and monthly rainfall, for both species. For either species, positive significant correlation existed betwen monthly forage yields and number of rainy days. Dhaman was more responsive than karera to all three rainfall factors involved.

Vegetation and its related biological processes are the products of a complex of interacting environmental factors, forces and conditions that function in "Time" dimension. Fortunately a small number of principal environmental factors permit, within a reasonable limit, an inference about the vegetation and its attributes. Thus Holdridge's (1947) classification of world vegetation and life zones was based on precipitation, biotemperature and evapotranspiration. This is particularly true in a desert ecosystem where moisture is probably the most critical factor determining the productivity. Accordingly, in this study the rainfall and its pattern were considered as the principal environmental factors. Dew, if any, was immeasurable. Ground water table, being at a depth of 40 feet, was not available to grasses.

The importance of precipitation and its timing has also been reported by Mueggler (1967). The production was 43% greater in 1964 than in 1963 and 14% greater in 1965 than in 1964. This increase was correlated with increases in precipitation both before and during the growing season.

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[1] The research work constituted a part of Ph.D. Thesis submitted by Dr. Ch. M. Anwar Khan to Range Management Section and graduate School of the University of Wyoming U.S.A. in 1968. Received November 5, 1969; accepted for publication June 1, 1970.

[2] Author acknowledges with thanks the guidance provided by Dr. Morton May, Professor of Range Management University of Wyoming, U.S.A. Thanks are due to Statistics Department of Agriculture College, University of Wyoming for help in analyses of data.

Thal Ranges

These desert grasslands or desert savanna (Fig. 1 and 2) lying between 30° and 33°N latitudes and 71° and 72°E longitudes occur on an older eolian deposits of sand, deposits of extinct streams, and longitudinal and complex dunes system with medium textured soils in valley flats. They are characterised by monsoon rains (July–September) while a little amount of rain may come in spring (Tables 1 and 2).

Excepting the months of December and January when the minimum may fall below 32 F, the temperatures are reasonably conducive to plant growth (Khan, 1968). The normal growing periods include February–April and July–September. Favourable moisture conditions may extend both the growing periods.

Procedures

The study was designed to determine relationships, if any, between monthly forage productions and

a) rainfall during the month,
b) rainfall during the previous month,
c) number of rainy days during the month, and
d) month of the growing period.

The monthly yields data for dhaman were collected in Dagarkotli and Kheriwala areas of Thal and those for karera were collected in Dagarkotli and Chubara areas. Dhaman sites (Fig. 3) in both projects had been reseeded in July 1964. The karera sites in Dagarkotli (Fig. 4) and Chubara projects were reseeded in August 1962 and July 1963, respectively. The site in each case was characterized by a uniform, flat topography lying between sand dunes. The soil on these flats was uniform sandy loam.

At each experimental site six 9.8 ft × 9.8 ft plots were permanently selected and marked with six inch iron nails. Each experimental unit had a uniform border of 1.1 feet. The entire area was fenced. Thus there were 12 plots clipped at monthly intervals for each species over two years period.

The experiment was started on February 1, 1965. The final clippings for the first year were made on October 1, 1965. All plots were rested through the winter and a subsequent clipping was made on February 1, 1966. The monthly clippings were continued through second year and the study was terminated on October 1, 1966.

The clippings of any particular plant included all vegetal parts, green or dry, above the stubble height of two inches. The clipped material was weighed air-dry in grams. The average of yields from six plots at one site was recorded as monthly yield for that month.

To eliminate between-plot variability of basal area of plants the basal area of all plants in each plot was determined on February 1, 1965. A metallic 9.8 ft × 9.8 ft grid, with 1,521 meshes of 3 inches 3 × inches each, was used for measurement of basal area (Khan, 1968). The yields were ultimately adjusted to the uniform basal area of 6.57% and analysed.

Standard rain guages were fixed at each experimental site and daily data recorded throughout the study period.

The partial and stepwise multiple correlation and re-

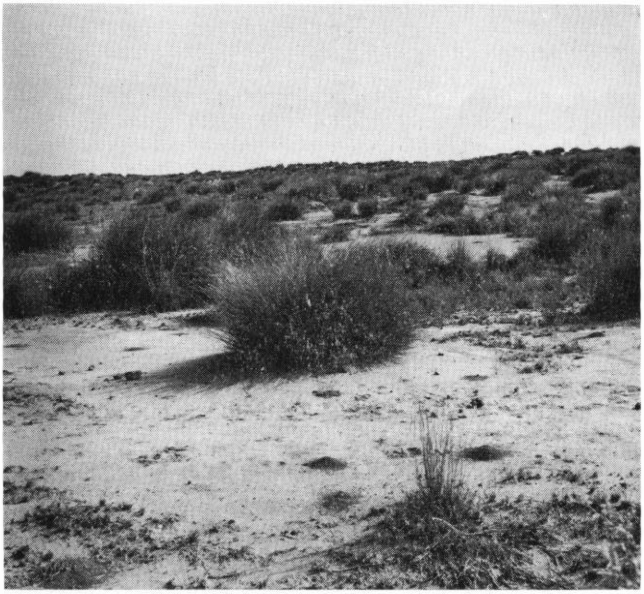

FIG. 1. Desert tall grass steppe, Thal, Pakistan *Pennisetum dichotomum* type. Photo, Sept., 1968.

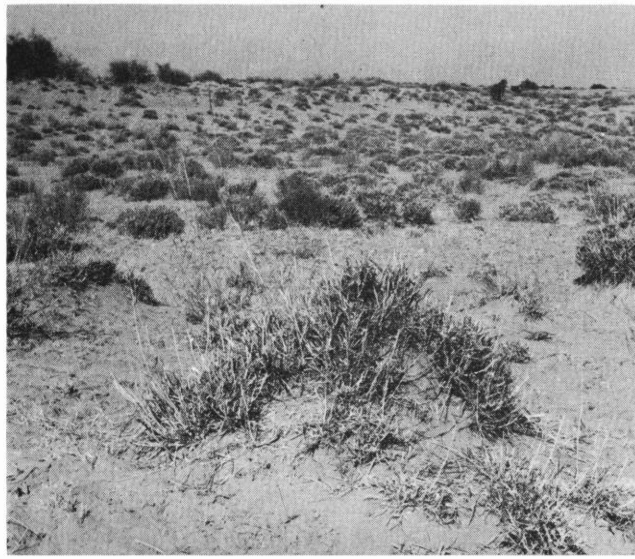

FIG. 2. Desert tall grass steppe savanna, Thal, Pakistan. *Elyonurus hirsutus/Acacia jacquemontii* type. Photo, January 1966.

gression analyses were made between monthly forage productions and other four variables, for each species. The data for each species over two years were combined for analyses. The significance for relationships was tested at 0.05 level (significant) and 0.01 level (highly significant).

Results

The actual average percent basal area of dhamn was 4.94 and 2.89 in Dagarkotli and Kheriwala respectively. The respective figures for karera at Dagarkotli and Chubara were 4.05 and 1.51.

The rainfall data and average air dry monthly forage productions for both species have been presented in tables 1 and 2.

Table 3 presents correlation matrix for dhaman and gives the measure of correlation among five variables involved. The rainfall during the month and number of rainy days during the month have highly significant positive partial correlation with monthly forage production. Though months of the growing period and rainfall during the previous

Table 1. Rainfall (inches) pattern[1] and averages air dry monthly forage yield (g) of dhaman (*Cenchrus ciliaris*) per 9.8 ft × 9.8 ft plot, adjusted on the plant basal area of 6.57%, during 1965–66 in Thal, Pakistan.

Year and place	Factor	Month of the growing season: Feb.	March	April	May	June	July	Aug.	Sept.
1965									
Dagar Kotli	Rainfall	0.00	0.48	1.52	0.00	0.00	8.92	3.00	0.00
	Rainy days	0	1	5	0	0	6	2	0
	Yield	0.19	24.38	211.64	33.13	3.82	406.40	266.08	182.84
1965									
K. Wala	Rainfall	0.50	0.48	1.52	0.00	0.00	2.47	3.62	1.28
	Rainy days	2	1	5	0	0	3	3	1
	Yield	38.21	18.83	315.94	3.23	0.00	206.71	0.00	77.99
1966									
Dagar Kotli	Rainfall	1.28	0.15	1.77	0.32	0.71	5.98	0.38	1.13
	Rainy days	5	1	5	1	1	6	1	2
	Yield	90.97	26.17	108.08	0.00	22.31	175.86	18.23	17.59
1966									
K. Wala	Rainfall	0.49	0.33	2.27	0.00	1.94	0.85	0.00	0.00
	Rainy days	3	1	3	0	2	1	0	0
	Yield	41.49	0.00	28.73	0.00	88.82	40.25	0.00	3.89

[1] No rainfall was received in October, November, December and January.

FIG. 3. Reseeded range site at Kheriwala, Thal, Pakistan. Grazed stand of *Cenchrus ciliaris* with scattered trees of *Prosopis spicigera* and *Salvadora oleoides*. Photo, Nov. 1965.

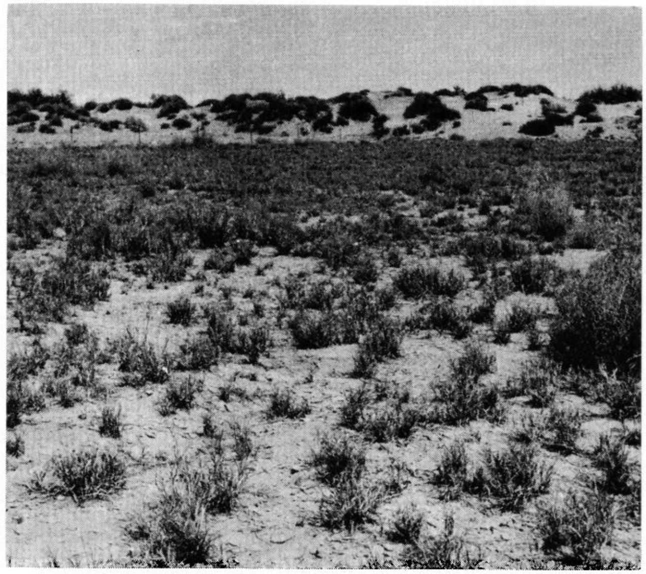

FIG. 4. Reseeded range site at Dagarkotli, Thal, Pakistan. Grazed stand of *Elyonurus hirsutus*, with natural sand dune in the background. Photo, March 1966.

months are positively correlated with monthly forage production, the correlation is not significant.

In respect of their importance in contributing towards the monthly forage yield of dhaman the order of independent variables, in decreasing importance, was the amount of rainfall during the month, number of rainy days during the month, rainfall during the previous month and the month of the growing period.

The stepwise multiple correlation and regression coefficients between monthly forage yield of dhaman and all the four independent factors considered were positive and highly significant.

The positive partial regression coefficient for the monthly amount of rainfall was highly significant. The regression coefficient for number of rainy days though positive, was nonsignificant. When the above two factors were considered in combination with the amount of rainfall during the previ-

Table 2. Rainfall (inches) pattern[1] and average air dry monthly forage yield (g) of karera (*Elyonurus hirsutus*) per 9.8 ft × 9.8 ft plot, adjusted on the plant basal area of 6.57% during 1965–66 in Thal, Pakistan.

Year and place	Factor	Month of the growing season							
		Feb.	March	April	May	June	July	Aug.	Sept.
1965									
Dagar Kotli	Rainfall	0.00	0.48	1.52	0.00	0.00	8.92	3.00	0.00
	Rainy days	0	1	5	0	0	6	2	0
	Yield	0.42	6.22	119.37	88.26	6.12	298.89	171.56	100.49
1965									
Chubara	Rainfall	0.50	0.48	1.52	0.00	0.00	4.31	2.62	1.30
	Rainy days	2	1	5	0	0	3	2	1
	Yield	24.69	61.41	200.45	151.68	0.00	155.17	0.00	196.44
1966									
Dagar Kotli	Rainfall	1.28	0.15	1.77	0.32	0.71	5.98	0.38	1.13
	Rainy days	5	1	5	1	1	6	1	2
	Yield	69.61	41.19	130.06	7.01	8.82	51.26	13.77	8.50
1966									
Chubara	Rainfall	0.44	0.37	1.74	0.00	0.98	1.91	0.00	0.42
	Rainy days	3	1	3	0	1	3	0	1
	Yield	0.00	39.41	0.00	4.32	339.97	149.82	0	3.25

[1] No rainfall was received in October, November, December and January.

Table 3. Correlation matrix for dhaman (*Cenchrus ciliaris*).

Variables	Rainfall during month	Rainfall previous month	No. of rainy days	Monthly forage production
Month of growing period:	0.23	0.44*	–0.15	0.16
Rainfall during month:		0.02	0.74**	0.70**
Rainfall previous month:			–0.19	0.14
No. of rainy days:				0.69**

* Significant at 0.05 level.
** Significant at 0.01 level.

Table 4. Correlation matrix for Karera (*Elyonurus hirsutus*).

Variables	Rainfall during month	Rainfall previous month	No. of rainy days	Monthly forage production
Month of growing period:	0.26	0.46**	–0.13	0.18
Rainfall during month:		0.01	0.73**	0.49**
Rainfall previous month:			–0.20	0.05
No. of rainy days:				0.37*

* Significant at 0.05 level.
** Significant at 0.01 level.

ous month, or the month of growing period the only significant regression coefficient was for number of rainy days during the month. The partial correlation between monthly yields and factors not entering into regression at any of the above steps of regression were nonsignificant.

The standardized regression coefficients for the rainfall during the month and number of rainy days were 0.437 and 0.359 respectively. The standardized regression coefficients for all the four independent factors, in their order of decreasing importance were: the number of rainy days during the month (0.506); the amount of rainfall during the month (0.306); the amount of rainfall in previous month (0.197); and the month of the growing period (0.079).

Based on the two most important rainfall factors the regression equation for dhaman, therefore, is as follows:

$$Y = 8.36 + 24.00\ X_1 + 19.52\ X_2$$

Where: Y = monthly air dry forage yield of dhaman in grams per 9.8 × 9.8 ft area

or = pounds of air dry forage yield per acre based on plant basal area of 6.57 percent

X_1 = amount of monthly rainfall in inches

X_2 = number of rainy days in the month.

The standard error of estimate is 72.6 lbs./acre, with coefficient of determination (r^2) as 0.55.

Table 4 presents the correlation matrix for karera and gives the measure of correlation among five variables involved. The rainfall during the month and the number of rainy days in the month have the highly significant and significant positive partial correlation with monthly forage production, respectively. Though months of the growing period and rainfall during the previous month are positively correlated with monthly forage production, the correlation is not significant.

In respect of their importance towards the monthly forage yield of karera the order of independent variables, in the decreasing importance, was the amount of rainfall during the month, month of growing period, number of rainy days in the month, and the amount of rainfall during the previous month.

The stepwise multiple positive correlation coefficients between monthly forage production of karera and other factors were significant only if rainfall during the previous month was not included.

The analyses of variance for the stepwise multiple regression indicated that monthly amount of rainfall has a highly significant positive regression relationship with the monthly forage yield of karera. The regression relationships between monthly yield and the amount of rainfall plus month of growing period, and the foregoing two factors plus the number of rainy days were significant. In the presence of a fourth independent variable, the amount of rainfall during the previous month, the multiple regression though positive was not significant.

Only the positive partial regression coefficient for the monthly amount of rainfall was highly significant. The partial correlation between monthly yield and factors not entering into regression at any of the steps of regression were nonsignificant.

The standardized regression coefficient for the monthly amount of rainfall was 0.491. Considering all the factors simultaneously, the standardized regression coefficients in their order of decreasing importance were: the amount of monthly rainfall (0.409), the number of rainy days in the month (0.085), the months of growing period (0.075), and the amount of rainfall during the previous month (0.025).

Based on the single most important rainfall factor the regression equation for karera, therefore, is as follows:

$$Y = 45.84 + 23.23 X_1$$

Where: Y = monthly air dry forage yield of karera in grams per 9.8 ft × 9.8 ft area

or = pounds of air dry forage yield per acre based on plant basal area of 6.57 percent.

X_1 = amount of monthly rainfall in inches.

The standard error of estimate is 81 lbs./acre, with coefficient of determination (r^2) as 0.24.

Discussion and Conclusion

It is evident that for monthly forage productions of dhaman as well as karera, the amount of monthly rainfall is of the utmost importance. The number of rainy days during the month is also of great importance. Though rainfall during the previous month had a positive influence, the effect was not significant. The climate and the soil factors tend to minimize the residual effect of rainfall during the months February to September.

The low correlation with the month of the growing period, emphasizes the importance of rainfall in these rangelands. The rainfall, not the temperatures (characteristic of months), is the limiting factor in these desert summer ranges.

A look at the standardized regression coefficients for both species allows for a comparative appreciation of dhaman and karera vs the four independent factors considered. In relation to the dependent variable of monthly forage yield dhaman was more responsive than karera to all three rainfall factors involved. Both species responded similarly to the month of the growing season factor.

The response pattern for each species is also of great interest. For dhaman, the amount of monthly rainfall was relatively twice as important as the number of rainy days in the month, three times as important as rainfall in the previous month, and seven times more important than the month factor.

For karera, the amount of monthly rainfall was five times more important than the number of rainy days as well as the months factor and 16 times more important than the rainfall of the previous month.

The study indicates the primary importance of monthly rainfall and number of rainy days within the month rather than month of the growing period or rainfall in the previous month. The forage availability will thus follow the usually predictable pattern of monsoon rains and warrant a planned grazing program. Total annual rainfall being restricted primarily to about four months (July, August/September and March/April) the active growth period of grasses follows the same pattern. This fact shall help devise a grazing program in tune with physiological requirements of two major range grasses.

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The Executive Secretary's office has attempted to maintain a list of persons who have back issues of the *Journal of Range Management* for donation, sale, or trade. However, difficulties have been experienced in keeping such a list current; hence, notice will be given in both the Journal and *Rangeman's News* of requests for back issues. Current requests are from:

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TECHNICAL NOTES

Imbibition by Alkali Sacaton Seeds[1]

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Highlight

Alkali sacaton (*Sporobolus airoides* Torr.) seeds imbibed water rapidly. Large seeds gained 47% and small seeds gained 71% of their dry weight within the first 30 min after wetting. The large seeds had gained 124% and the small seeds 165% of their dry weight after 72 hr.

The purpose of this study on alkali sacaton (*Sporobolus airoides* Torr.) was to provide a basis for future studies on (1) the amount of imbibition necessary for germination, for photo effects on germination, and before high temperatures affect germination, and (2) the effect of periodic wetting and drying on germination.

Literature Review

Water uptake by seeds, the first process of germination, is known as imbibition. The amount of water imbibed is determined by (1) the composition of the seed, (2) the permeability of the seed coat to water, and (3) the availability of water.

All seeds must imbibe moisture before the germination process can begin (U.S. Dep. Agr., Forest Serv., 1948; Baker, 1950). The amount of imbibition necessary to initiate germination depends largely upon the species (Larson, 1968). Hunter and Erickson (1952) reported a minimum moisture requirement for germination of 30, 26, 50, and 31% for corn, rice, soybeans, and sugar beets, respectively.

Goo (1951) and Asakawa (1956) showed that water uptake by coniferous tree seeds can be divided into three phases: (1) rapid initial uptake, (2) a tapering-off period of slow uptake, and (3) distinctly increased uptake resulting from metabolic activity in germination.

Larson (1968) found that, in a 24-hr period, pea seeds (*Pisum sativum* L.) submerged in water with seed coats intact and with seed coats removed imbibed 20 and 17 g of water per 100 seeds, respectively. Pea seeds without coats had a greater initial imbibition rate, but seeds with and without coats soon imbibed water at the same rate. Approximately 85% of the water was imbibed during the first 5 to 6 hr.

No work was found reporting on imbibition by range grass seeds.

Procedures

Small air-dry samples (0.50 g) of large and small alkali sacaton seeds were sandwiched between germination blotter papers saturated with distilled water. After the seeds had imbibed for the desired time, the blotter covering the seeds was removed and the blotter holding the seeds was placed on a dry blotter to eliminate free water. The seeds were then scraped into a weighing vessel and weighed. The percentage of weight change (dry weight basis) was determined at intervals ranging from 5 min to 72 hr after the start of imbibition. A Mitscherlich curve (Snedecor, 1956) was fitted to the data. Separate 0.50-g samples were used for each determination.

Results and Discussion

The large seeds gained 47% of their dry weight during the first half hr after the start of imbibition (Fig. 1). They continued to gain weight at a constant, though less rapid, rate through the 4th hr. The large seeds lost 8% of their weight during the 5th hr, and gained only 5% from the 6th through the 9th hr. Thereafter, they gained steadily to 118% of their original weight after 36 hr. Some of this gain was due to weight gains by the developing seedlings, as sprouting began during the 28th hr. The weight increase from the 36th through the 72nd hr was only 8%. There were no unusual weight changes associated with the appearance of sprouts.

The weight of the small seeds increased more rapidly, and their final percentage increase in weight was greater than that of the large seeds (Fig. 1). The small seeds gained 71% of their original weight during the first half hr after the start of imbibition, and had doubled their weight after 4 hr. The small seeds did not lose weight during the 5th hr as did the large seeds, but their rate of gain decreased during the 5th and 6th hr. This period of slow gain corresponded to the period during which the large seeds lost (5th hr) and gained only slightly (6th to 9th hr) in weight. As with the large seeds, the weight of the small seeds increased from the 10th through the 36th hr. From 36 through 72 hr the weight gain of the small seeds was 25%.

Sprouts from the small seeds were first visible during the 32nd hr. There were no unusual weight changes associated with the appearance of sprouts; weight changes after the 32nd hr were due to weight changes of the developing seedlings, however, and not to imbibition by the seeds.

Changes in weight of both large and small seeds during the 5th and 6th hr may be due, at least in part, to solvation of the seed coat and exudation losses. A mucilaginous substance was present on the blotters after seeds had imbibed for more than an hr were removed. Microscopic examination revealed that the outer portion of the seed coat of alkali sacaton is transformed to mucilage upon wetting (Figs. 2 and 3). Also, a brown exudate was present on the blotters after the seeds had imbibed for more than 2 hr; the extent of staining increased through the 7th hr, then remained constant. Exudation losses appeared to be slightly greater from the large seeds, which probably accounts for a part

[1] Received May 25, 1970; accepted for publication July 3, 1970.

[2] Forest Service, U.S. Dept. of Agriculture, with central headquarters maintained at Fort Collins in cooperation with Colorado State University; author is located at Albuquerque, in cooperation with the University of New Mexico. Research reported here was conducted in cooperation with the Bureau of Land Management, U.S. Dept. of the Interior. Extract from dissertation completed in partial fulfillment for the Ph.D. in Range Management, Department of Watershed Management, University of Arizona.

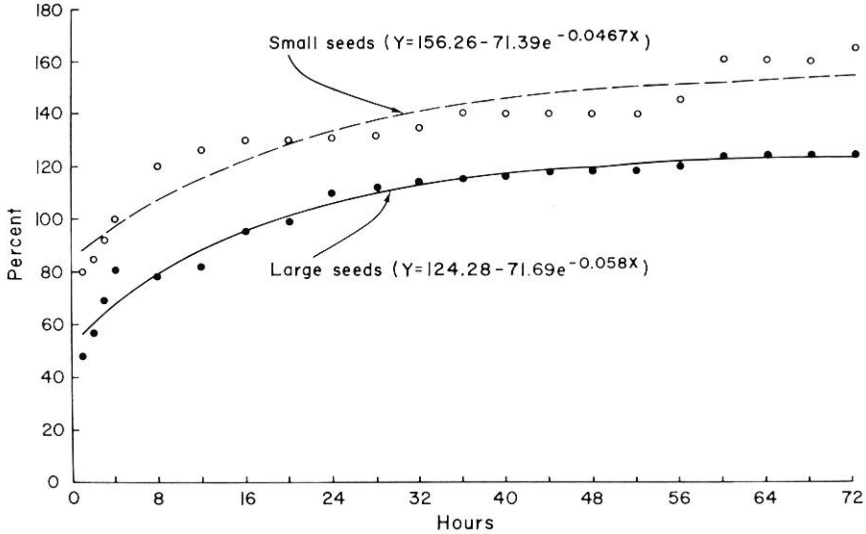

FIG. 1. Percentage of imbibition (dry-weight basis) by large and small alkali sacaton seeds, in relation to number of hours after start of imbibition.

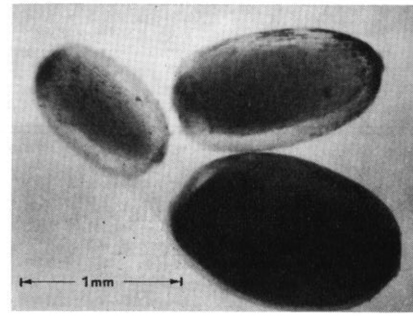

FIG. 2. Large, medium and small alkali sacaton seeds after 2 hr imbibition: note that the thickness of the mucilaginous membrane is inversely proportional to seed size.

of their loss in weight during the 5th hr after the start of imbibition.

It was initially reasoned that the large seeds lost more mucilage than the small seeds, and that this loss occurred on about the 6th hr after the start of imbibition. Microscopic examination revealed that this theory is not necessarily true, however, because (1) the amount of mucilage surrounding the seeds was approximately inversely proportional to seed size (Fig. 2), and (2) the mucilage did not separate from the seed at any specific time after the start of imbibition; in fact, the mucilage did not separate from the seeds at all unless it was removed by some mechanical means. It should be noted, however, that the mucilage can be separated from a seed that has imbibed for about one hr by merely touching the seed or swirling it about in water.

The mucilage appears as a film about the seed immediately after the seed is wetted, and the thickness of the film increases for several hr thereafter (Fig. 3). Thus it is not clear why the large seeds lost weight during the 5th hr after the start of imbibition. If the decrease had been due to loss of mucilage, the loss from the small seeds would have been greater because the amount of mucilage in proportion to the remainder of the seed is greater. Weight loss apparently was due primarily to a greater exudation loss by the larger seeds. Large seeds have a greater percentage of endosperm and thus a greater percentage of water-soluble carbohydrates that are lost during imbibition.

It was also considered that weight changes from the 5th to the 9th hr were due to respiration losses. To test this hypothesis, 50-g samples of seed were placed in thermos bottles and wetted, a thermometer was inserted into the seeds, and the mouth of the thermos sealed with cotton. The test was replicated twice for both large and small seeds. The premise was that, if the loss in weight was due to respiratory losses, the temperature would rise considerably on about the 4th hr (the time corresponding to the period of loss in weight of large seeds during

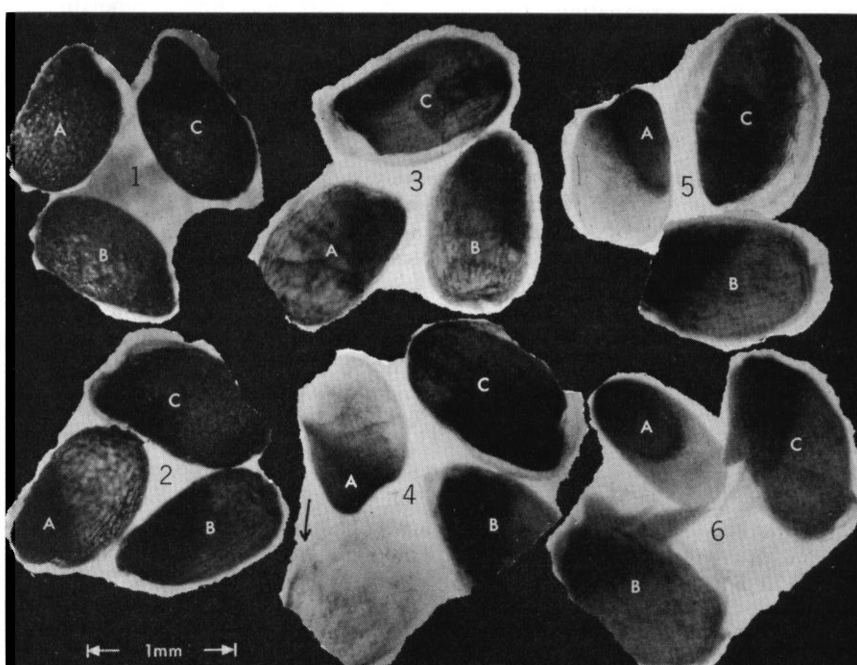

FIG. 3. The appearance of alkali sacaton seeds from prior to the start of imbibition until shortly after germination. All seeds are floating in distilled water. 1—seeds dry; 2—after 5 min imbibition; 3—after 1 hr imbibition; 4—after 5 hr imbibition (the mucilaginous membrane was removed by simply swirling the water beside the seed with the point of a dissecting needle); 5—after 24 hr imbibition; 6—after 48 hr imbibition, and 1 hr after visible signs of germination appeared (note that the mucilage has begun to separate from seed C, apparently due to the action of the radicle and plumule emerging from the seed).

imbibition). The test did not verify this premise; the only appreciable temperature change occurred during the first 30 min.

After 72 hr the large seeds had gained 124% and the small seeds 165% of their original weight. The difference in amount of apparent imbibition gain may be because the small seeds contain a greater proportion of mucilage. This mucilage is highly absorbent, and as a consequence, the small seeds imbibed a higher percentage of water.

Conclusions

In this study, imbibition of water by alkali sacaton seeds progressed through three phases: (1) an initial period of rapid uptake lasting for approximately 4 hr, (2) a tapering-off period of slow or negative uptake (the large seeds actually lost weight during this period) that lasted approximately 7 hr in the large seeds and 2 hr in the small seeds, and (3) a period of gradual increase that lasted until sprouting became evident: the 28th hr in large seeds and the 32nd hr in small seeds.

The second stage apparently was due to exudation loss and possibly some loss of the mucilaginous membrane which envelops the seeds. The smaller seeds contained a higher proportion of the highly absorbent mucilage, and thus imbibed more moisture and at a higher rate than the large seeds.

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Estimating Digestible Energy from Digestible Dry and Organic Matter in Diets of Grazing Cattle[1]

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Highlight

Regression equations for six methods of expressing the relationship between digestible energy and digestible dry or organic matter were developed from digestion trials conducted with cattle grazing native range forage. Concentrate feeds supplemented the grazing animal's diet in some trials. The results of this study indicated that the laborious determination of digestible energy could be replaced by a simple determination of digestible dry or organic matter. Supplementation with concentrates did not change the relationship between digestible energy and digestible dry or organic matter.

Moir (1961) showed the close relationship between digestible dry matter and digestible energy in ruminant diets by summarizing data from the literature involving hand fed feedstuffs. The objective of the present study was to examine the relationship between digestible energy and digestible dry or organic matter when determined under range conditions.

Experimental

Data from five independent studies were obtained from digestion trials conducted with cattle grazing native

Table 1. Trial locations, number of observations per trial, season of use and supplementary regimen.

Trial location	Number of observations	Season of use	Supplementary regimen
SB[a] 1964	3	Early summer	None
SB 1964	4	Early summer	None
SB 1964	4	Mid summer	None
SB 1964	5	Mid summer	None
SB 1964	6	Late summer	None
SB 1964	6	Late summer	None
SB 1965	5	Early summer	None
SB 1965	5	Early summer	None
SB 1965	5	Mid summer	None
SB 1965	3	Mid summer	None
SB 1965	3	Late summer	None
FR[b] 1966	5	Winter	None
NP[c] 1967–8	14	Winter	Yes
NP 1969	7	Winter	None
NP 1969	7	Winter	Yes

[a] Scotts Bluff Experimental Range
[b] U.S.D.A. Beef Cattle Research Station at Fort Robinson
[c] University of Nebraska North Platte Station

[1] Published with the approval of the Director as Paper No. 2786, Journal Series, Nebraska Agricultural Experiment Station. Received February 20, 1970; accepted for publication July 7, 1970.

[2] Present address: Squaw Butte Experiment Station, Burns, Oregon.

[3] Present address: Department of Animal Science, Colorado State University, Fort Collins, Colorado.

[4] Present address: University of Nebraska, North Platte Station, North Platte, Nebraska.

Table 2. Estimated linear regression parameters, using the model y = a + bX, with their respective standard errors and the estimated standard error of estimate ($s_{y \cdot x}$) and coefficients of determination (r^2).

Comparison	Regression parameter a	b	$s_{y \cdot x}$	r^2
DE vs DMD	0.54 ± 1.41	1.02 ± 0.03	2.32	.939
DE vs OMD	−8.13 ± 1.06	1.07 ± 0.02	1.51	.956
Kcal DE/g DM vs DMD	0.18 ± 0.07	0.038 ± 0.001	0.195	.891
Kcal DE/g DM vs OMD	−0.10 ± 0.08	0.039 ± 0.002	0.118	.891
Kcal DE/g OM vs DMD	0.04 ± 0.09	0.048 ± 0.002	0.142	.903
Kcal DE/g OM vs OMD	−0.36 ± 0.08	0.050 ± 0.002	0.120	.917

range (Streeter, 1966; Rittenhouse et al., 1970). The forages studied represented a wide range of phenological development. Some of the animals also received from 6.1 to 24.5 g of a concentrate supplement per kg metabolic body weight (BW)$^{0.75}$. Trial locations, number of observations per location, season of use, and supplementary regimen are given in Table 1.

Digestible dry and organic matter were estimated using lignin as an internal indicator as described by Rittenhouse et al. (1970). Lignin was determined by the procedure outline by Van Soest (1963) in trials at the Scotts Bluff Experimental Range, and by Van Soest and Wine (1968), as modified by Rittenhouse et al. (1970), in all other trials. Samples of the diet were collected via esophageal fistulae and total fecal collections were obtained from animals equipped with harnesses and bags.

In order to establish the most desirable means of expressing the relationship between dry matter digestibility (DMD) or organic matter digestibility (OMD) and digestible energy (DE) six comparisons were made:

% DE	vs	% DMD
% DE	vs	% OMD
kcal DE/g DM	vs	% DMD
kcal DE/g DM	vs	% OMD
kcal DE/g OM	vs	% DMD
kcal DE/g OM	vs	% OMD

In developing regression equations for the six methods of comparing DMD or OMD with DE, the data were analyzed according to the linear model Y = a + bX. Data within each location and year were grouped for purposes of regression. Homogeneity of regression coefficients for each location and year was tested by an appropriate F test in an analysis of covariance. Predicted or adjusted values were also tested in an analysis of covariance. The influence of supplements on the relation between digestible energy and digestible dry or organic matter was also evaluated by testing adjusted means in an analyses of covariance.

Results and Discussion

The test for homogeneity of regression coefficients among trials indicated no significant differences at the 0.05 level of probability for comparisons involving either dry matter or organic matter. Likewise, no differences ($P > .05$) were found among predicted or adjusted values. Including supplements in the dietary regimen did not significantly ($P > .05$) alter the predicted or adjusted values. Estimated linear regression parameters, their respective standard errors, standard errors of estimate ($s_{y \cdot x}$) and the coefficients of determination (r^2) are shown in Table 2.

Slightly more of the total variation was accounted for when digestible energy was compared with OMD vs DMD (r^2 = .956 and .939, respectively), but the precision of estimating a pre-

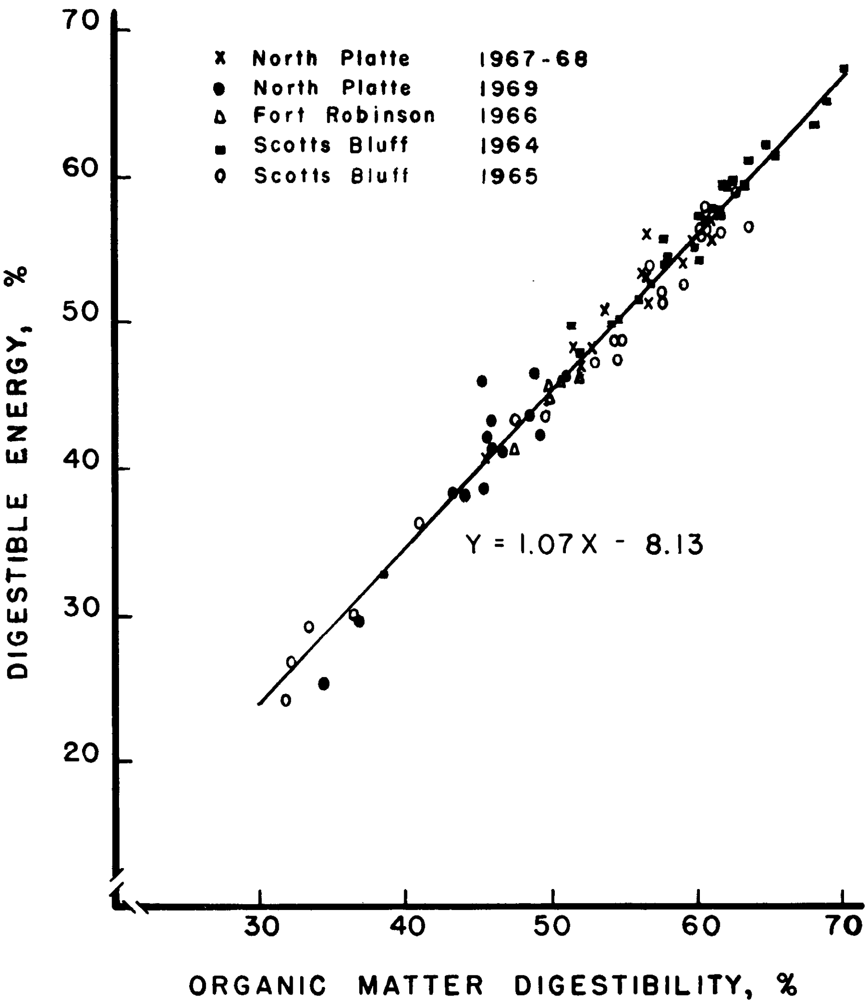

FIG. 1. Relationship between digestible organic matter and digestible energy determined in grazing trials.

dicted value was much higher with OMD ($s_{y \cdot x} = 1.51$ and 2.32, respectively, Table 2). Samples collected via esophageal fistulae are known to be contaminated with soil and salivary ash to varying degrees (Van Dyne and Torell, 1964); however, a comparison of slopes of the regression lines for DE vs DMD and OMD indicated that the variable ash content of the diet had little influence on energy digestibility. Expressing digestible energy as a percent was superior to an expression as a content of dry or organic matter. The close relationship between digestible energy and digestible organic matter is shown in Figure 1. All but three of the points fall on or within a 95% confidence interval of the estimate of a population individual.

Even though digestible energy was predicted with less precision from DMD than OMD, the parameters would suggest that DMD is an excellent estimate of the digestible energy intake of a grazing animal. For all practical purposes the Y intercept was found to be at zero and the slope of the regression line was a 1 : 1 ratio between digestible energy and DMD, i.e., $Y = 1.02X + 0.54$. This agrees well with the equation given by Moir (1961): $Y = 1.006X - 2.013$ where Y was percent digestible energy and X was percent DMD. A similar agreement was found between the present work and the equation given by Moir (1961) when digestible energy was expressed as a content of dry matter ($Y = 0.038X + 0.18$ and $Y = 0.046X - 0.192$, respectively). These findings suggest that either DMD or OMD may be used with the above equations for predicting DE of similar type native range forage.

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MANAGEMENT NOTES

Freeze vs. Fire Branding as Methods of Beef Cattle Identification[1,2]

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Highlight

Over a three-week period in April 1969, 200 Hereford females, ranging in age from 15 months to 10 years, were branded with their individual herd numbers on each side of the rib cage just behind the shoulder with either freeze or fire brands. The brands were evaluated for legibility on January 14, 1970, using the following scoring system: 1 = no visible numbers; 2 = visible numbers, but illegible; 3 = incomplete numbers, but able to understand after study; 4 = easily recognizable numbers, but with breaks or unbranded areas; 5 = instantly recognizable, complete unbroken numbers. Variation among brand scores was partitioned into age of cow, side of cow, type of brand and the two-way interactions between these three effects. Type of brand was the only significant source of variation influencing the brand scores, and the fire brands (4.35) were more legible than the freeze brands (3.75). However, it should be stressed that neither type of brand was legible at the time of evaluation without first clipping the brands.

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[2] A publication of Southern Regional Beef Cattle Breeding Project, S-10.

Finding a satisfactory method of identifying beef cattle has been a problem confronting producers for years and is a must for the producer who maintains and utilizes records on his cattle. Various methods of identification such as neck chains, ear tags and fire branding all have their advantages and disadvantages. However, to be reliable, any method of beef cattle identification should be permanent and legible at all times. Most neck chains and ear tags are legible but are far from being permanent. Neck chains often require adjustment and are subject to wear and eventual loss, while many types of ear tags are rather easily lost, especially when used on bulls. Fire branding serves as a permanent method of identification, but fire brands are not always legible on certain types of cattle, especially those which tend to have long hair growth during the fall and winter. To alleviate this problem, many producers resort to clipping of fire brands to increase their legibility during the winter. However, this can be a rather tedious and time consuming chore where large numbers of cattle are involved. To alleviate some of the problems often encountered with the use of either fire branding, neck chains or ear tags, freeze branding was developed with the idea that this method would provide a more reliable method of identifying cattle. This method has gained rather widespread attention in recent years, and a limited amount of research work has been conducted with freeze branding but in most cases results are based on a limited number of animals.

The purpose of this study was to compare freeze branding with fire branding as methods of beef cattle identification when the comparison was made on a rather large number of breeding females.

Materials and Methods

Over a three-week period in April 1969, 200 Hereford females, ranging in age from 15 months to 10 years, were branded with their individual herd numbers on each side of the rib cage just behind the shoulder with either freeze or fire brands. This particular site was chosen since the branding was done just prior to the beginning of a 75-day breeding season, and it was reasoned that if the brands were placed on the rib cage rather than the rump, there would be less sloughing of skin from the branded area, due to mounting by bulls and other cows as the cows came into heat. Also, branding on the rib cage just behind the shoulder provided more surface area on which to apply the large branding irons used for this study and, also, provides a quick way of locating a particular cow at feeding time during the winter (critical time for accurate animal identification in the herd in which study was conducted). As silage is fed during the winter, the cows will line up at the silage trough and drop their heads to eat; consequently, the brands are easy to detect by merely walking in front of the cows on the opposite side of the silage trough.

For this study, side of cow served as the experimental unit rather than each individual cow *per se*. To determine which side of each cow would be fire branded and which side would be freeze branded, the experiment was designed as a 2 × 2 factorial arrangement of treatments in a randomized complete block design where type of brand (freeze vs. fire) and side of cow (left vs. right) served as the two factors and age of cow served as blocks. Side of cow was determined when standing behind rather than in front of the cow. The 200 Hereford cows were randomly allotted to the four treatments on a within age of dam basis. Allotting of cows to the four treatments permitted each cow to be either fire or freeze branded on either the right or left side. In addition, once a cow was branded according to her allottment in the factorial arrangement of treatments, the cow also was branded on the opposite side with the other type of brand. Thus, the individual herd number of each cow, which consisted of from two to four digits, was fire branded on one side of the cow and freeze branded on the other side. Variation among brand scores was partitioned into age of cow, side of cow, type of brand and the two-way interactions between these three effects.

Five-inch copper-tipped irons were used for the fire branding and five-inch copper freeze branding irons were used for the freeze branding. The fire brands were heated using a butane branding iron heater and the freeze brands were chilled in dry ice and 95% ethyl alcohol 45 to 60 minutes before being used. Prior to freeze or fire branding, hair on the rib cage just behind the shoulder was clipped and excess "scurf" removed from the clipped area with a stiff brush. For the side of each cow that was freeze branded, the clipped area was wetted with a sponge dipped in 95% ethyl alcohol, and the freeze brands were applied immediately for a duration of 50 to 55 seconds. This time interval was chosen with the idea that if the freeze brands did not result in a regrowth of white hair, the brands would appear as legible scars in a manner similar to what occurs for fire branding.

Generally, one person did all the fire branding and one person did all the freeze branding. This provided for some partial confounding between personnel and type of brand; however, this procedure was deemed necessary, since the person doing the fire branding had previously had experience only with fire branding the person doing the freeze branding had previously had experience only with freeze branding.

The brands were evaluated first for legibility on January 14, 1970, just prior to the beginning of the 1970 calving season. This time was selected for evaluation since the need for accurate parental identification in the herd in which the study was conducted is greatest during the calving season. The following scoring system was used to evaluate the brands:

Score	Interpretation
1	No visible numbers.
2	Visible numbers, but illegible.
3	Incomplete numbers, but able to understand after study.
4	Easily recognizable numbers but with breaks or unbranded areas.
5	Instantly recognizable, complete unbroken numbers.

Due to long hair growth covering the brands at time of evaluation, neither freeze nor fire brands were legible so both sides of each cow were clipped prior to evaluation of the brands (Fig. 1). The brands were evaluated by one person immediately after the sides were clipped at a distance of 6 to 8 feet as each cow stood in a squeeze chute. Also, the brands were evaluated by another person from horseback three weeks later as the cows grazed on pasture. An average of the two scores was taken as the score for each brand. In the case where a cow's number consisted of two or more digits, all

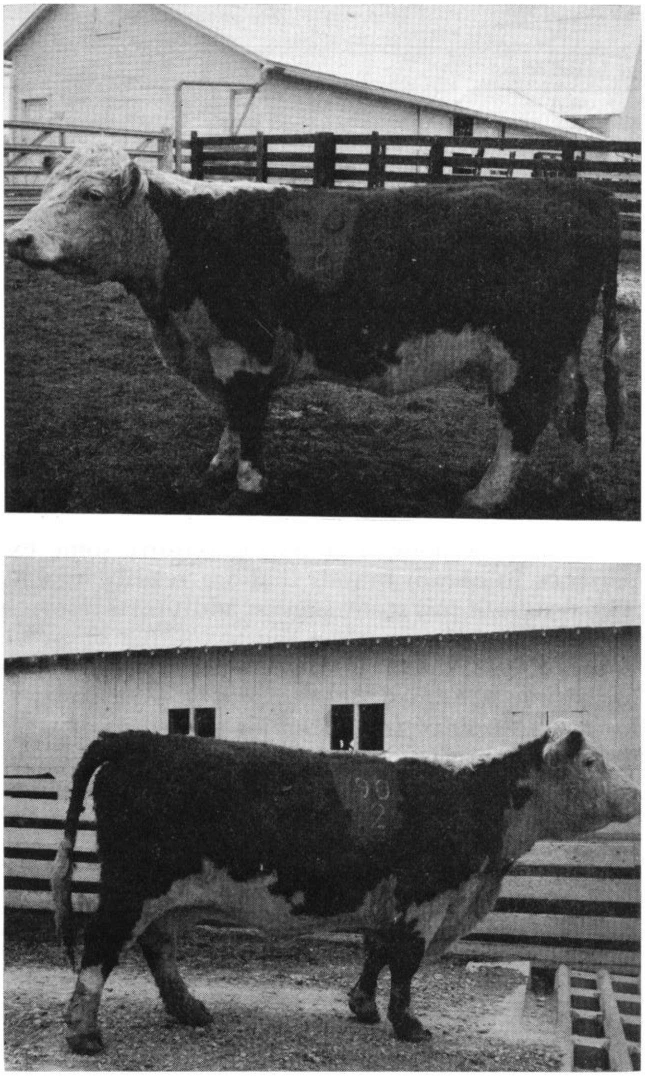

FIG. 1. Fire (upper photo) and freeze (lower photo) brands of cow number 90/2.

digits were evaluated together for legibility. For instance, if one or more of the digits of a four digit number were incomplete, but the other digits were legible, the entire brand was scored 3. This method of scoring was used since all digits of a number need to be legible for the branding procedure to be successful as a permanent method of identification.

Results and Discussion

The average brand score for the 200 Hereford cows was 4.1, with an overall standard deviation of 0.9. This average score indicates that most of the brands were easily recognizable but also suggests that several of the brands had some breaks or unbranded areas. The distribution of average brand scores by type of brand is shown in Table 1.

Type of brand was a significant source of variation; whereas, age of cow and side of cow were both nonsignificant sources of variation influencing the brand scores. Also, the age × side, age × brand and side × brand interactions were nonsignificant.

Means for type of brand indicated the fire brands (4.35) were more legible than the freeze brands (3.75). The distribution of brand scores presented in Table 1 shows that 168(84%) of the fire brands were scored 4 or greater; whereas, only 106(53%) of the freeze brands were scored 4 or greater. Table 1 also shows that 32(16%) of the fire brands received a score of 3.5 or less which suggests that these brands were not very legible. In most cases, the numbers six and nine were responsible for the poor legibility of these fire brands. The same branding iron was used for both of these numbers and if the iron was overheated at the time of application, some blotching of these two numbers usually occurred. Since the lower part of the number six usually blotched as compared to the upper part of the number nine, no real problem was encountered in distinguishing between these two numbers. However, in certain cases, it was difficult to distinguish between a blotched six or nine and a blotched zero.

At the time the brands were evaluated, the presence of white hair on the freeze brands was slight, although most of the freeze brands did have some white hair growth present around the periphery of each number. In fact, the legible freeze brands were similar in appearance to the legible fire brands, except the presence of scar tissue was not as evident on the freeze brands as on the fire brands. No certain number tended to be responsible for the poor legibility of the freeze brands as was the case for the fire brands.

The literature contains no direct comparison between freeze and fire branding as methods of beef cattle identification; however, several workers have published information describing various freeze branding procedures (Farrell et al., 1966; Brown and Williams, 1968; Hooven, 1968; Schalles et al., 1968; Kambitsch et al., 1969; Ely and Launchbaugh, 1969; Farrell et al., 1969). After comparing dry ice plus ethyl alcohol and liquid nitrogen as refrigerants to chill steel, aluminum and copper irons for freeze branding of 60 adult Hereford cows, Farrell et al. (1966) concluded that freeze branding can be successfully accomplished on adult cows by a 30-second application of a chilled copper iron to the clipped skin wetted with alcohol using either refrigerant.

It is well to emphasize that the present study was conducted using Hereford females that tend to have long hair growth during the fall and winter, and the results obtained probably are not applicable to other breeds such as the Angus or to "slick-haired" females of the Hereford breed. As previously stated, the results suggest that the fire

Table 1. Distribution of brand scores by type of brand.

Type of brand	Average brand score[a]								
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Fire									
No.	0	0	2	3	8	19	33	66	69
Percent	0.0	0.0	1.0	1.5	4.0	9.5	16.5	33.0	34.5
Freeze									
No.	2	6	12	16	25	33	36	25	45
Percent	1.0	3.0	6.0	8.0	12.5	16.5	18.0	12.5	22.5
Total									
No.	2	6	14	19	33	52	69	91	114
Percent	0.5	1.5	3.5	4.8	8.3	13.0	17.3	22.8	28.5

[a] Average of two personnel doing scoring.

brands were more legible than the freeze brands. However, it should be stressed that neither type of brand was legible at the time of evaluation without first clipping the brands. Hence, regardless of which method of branding works best under a given situation, it appears that both types of brands still have to be clipped during the winter to provide for prompt, accurate identification of the type of cows used for the present study. This clipping may not be necessary where cows are branded that have a relatively short hair coat during the fall and winter. Also, when used for identification of Angus cows, it is conceivable that freeze brands would require no clipping since the white hairs of the freeze brands should show up better than on Hereford cows.

When successful, freeze branding can be a very satisfactory method of beef cattle identification; however, freeze branding of a large number of cattle can be a tedious and time consuming process especially when the brands are applied for a 50- to 55-second duration as they were in the present study. To reduce the time required to freeze brand each animal, Ely and Launchbaugh (1969) used a multiple iron holder to freeze brand 300 Hereford steers. Time required to apply three number brands was reduced from 150 seconds when irons were applied individually to 40 seconds when the multiple iron holder was used. Of the 300 steers freeze branded, 231(77%) had legible brands eight months after branding, 30(10%) had brands marginal in legibility and 39(13%) had brands that could not be readily identified.

In contrast to the time required for freeze branding, fire branding can be done relatively fast; however, both methods of branding require some experience to obtain brands that are readily legible. The results of this study suggest additional research work is needed to perfect the technique of freeze branding beef cattle. It appears that additional information is needed on the proper time interval for application of freeze brands as well as at what time of the year would best results be obtained with freeze branding. Also, it is possible that more favorable results could be obtained by placing the freeze brands at different locations on the body. Hooven (1968) freeze branded 10 dairy heifers ranging in age from 3 to 15 months and noted differences in response between anatomical sites of the same animal.

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Australian Grasslands. (Edited by) R. Milton Moor, Australian National University Press, Canberra. 455 p. 1970. $(A)15.00.

This book is a comprehensive presentation of the Australian Grasslands and their uses and capabilities. Thirty-five authors contributed to bring together the latest available information on the important subject. Well illustrated and documented with 60 figures, 48 plates, 5 colored maps, 65 tables, and over 1200 references, the compilation should serve well as an authoritative source reference on the vegetation of Australia and its uses.

The scope of the compilation is shown by the four sections: 1) The environment, 2) the grazing lands and pastures, 3) factors in productivity, and 4) grassland production. Each of the 28 chapters was prepared by different authors. Each major plant type is treated as to its distribution, soils, vegetation, uses, and, where applicable, conversion and management. Although the book it titled "Australian Grasslands," woodlands, forests, and heaths are treated as well. The book is recommended as an excellent reference on the renewable resources of Australia. —*Elbert H. Reid,* Fort Collins, Colorado.

How to Attract, House and Feed Birds. By Walter E. Schutz. The Bruce Publishing Co., New York, N. Y., 196 p. illus. $7.95.

This is a new and revised edition of the Schutz book first published in 1950 under a different title. The material has been reorganized under six easy-to-find units. The short opening chapter emphasizes the ecological approach, with the central idea that the survival of our wild birds bears a direct relationship to our own well-being. The second chapter, titled "Bird Watching," deals with both rural and urban parts of the country and includes information on identification, banding, and popular trees, shrubs, and other plants that attract birds. The next three chapters are the real heart of the volume and treat with bird requirements for food, water, and shelter. They contain specific information on bird diets and preferences for food and nesting. There are detailed plans and instructions for building and placing dozens of types of feeders, baths, and houses—each suited to different kinds of birds, situations, or seasons. The final chapter has helpful hints on winter care, natural enemies, and useful references. Birds can be intensely interesting and demanding of respect, as we have found since our retirement to five acres of grass, brush, and trees in west central Illinois. We will use this book. Range men from western ranch operators to government employees in Washington, D.C. will find something of interest in it.—*R. S. Campbell,* Quincy, Illinois.

The Last of the Loners. By Stanley Paul Young. The Macmillan Company, New York, N. Y. 316 p. illus. 1970. $9.95.

After a brief history of wolves and how they were regarded since ancient times, the author focuses on the demise of nine grey wolves by Government hunters of the old Biological Survey (now the Bureau of Sport Fisheries and Wildlife, U.S.D.I.). The book is written in an interesting manner and obviously is fiction based on fact since the author attempts to follow the reasoning of the wolves being featured. The habits of the wolves are discussed—their life history, how they avoided traps and poisons, and how they were eventually caught by the professional hunter. It is immediately evident that the author knew a great deal about wolves, their way of life, strengths, and weaknesses.

While the information on the cover flap states that Stanley Young wrote the book because of deep respect and admiration for the grey wolf, and his concern for the survival of this endangered species, this is not readily apparent from the book. Rather it is a story of the professional hunter, his desire to kill off the last wolf, his dedication, and his accomplishment of this end—in Colorado, at least. The wolves are variously referred to as "animal criminals," "outlaws," "killers," "she-devils," "murderers," "master criminal" and other equally descriptive names. While attempting to show the cunningness of the wolves, the book does a better job of emphasizing the great havoc they wrought on the livestock industry, and how, in the end, they always were caught. Woven into the story also is the close working relationship between the professional hunter and the stockmen, the disdain of the Government hunter for the bounty hunter, and the conflict between the "Nesters" and the hunters and stockmen.

The book should be interesting reading to students of the history of resources of the West, their development and use. Well illustrated and interestingly written, it is recommended reading for those interested in the relationship of wolves to the early development of western ranching.—*Elbert H. Reid,* Fort Collins, Colorado.

NEW PUBLICATIONS

Proceedings, Annual Tall Timbers Fire Ecology Conference, No. 9, April 10–11, 1969, brings together another fine set of papers. The scope of the conferences continues to broaden—this book includes contributions from Hawaii, Northwest Territories of Canada, Southern Australia, and several states of the contiguous U.S.A. 292 p. Published by Tall Timbers Research Station, Tallahassee, Florida.

Raymond F. Dasmann's "A Different Kind of Country," first published in 1968, is now available as a Collier paperback for $1.95, published by Macmillan. "This book is a plea for diversity . . . . in the hope that the prevailing trend toward uniformity can be arrested and the world kept a fit place for the greatest possible human variety." Although the book was written nearly four years ago, "the problems remain the same and the principles behind them are unchanging."

Volume 3 of the series "Wild Flowers of the United States," has been published by the New York Botanical Garden and McGraw-Hill Book Company. This series is compiled and edited by Dr. H. W. Rickett of the New York Botanical Garden. A review of volumes 1 and 2 of this series was published in this Journal (21: 271–272).

Volume 3 of the series deals exclusively with the wild flowers of Texas. This volume has the same high quality of photography and construction as the preceding volumes. Of the more than 4000 flowering plants in Texas (including grasses, sedges, trees, cacti), some 2700 herbaceous wild flowers are considered in this volume. More than 1000 color plates are presented in this two-book volume selling for $44.50. Book 1 has 274 pages plus xii and book 2 has 279 plus v and the two books fit into a sturdy case.

Plans are for Volume 4 of the series to cover the Southwest (New Mexico, Arizona, and southern California), Volume 5 the Pacific Northwest, and Volume 6 the Rocky Mountains and Great Plains. A complete index for all volumes will be published last.—*George M. Van Dyne,* Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado.

Results of Annual Election and ASRM Special Meeting

Name of Society To Be Changed

As indicated in the October 1970 issue of *Rangeman's News* and by the proxy ballots mailed to the membership last October 1, a special meeting of the American Society of Range Management was held at the Society's offices on December 11, 1970. The purpose of the meeting was to vote on proposed amendments to ASRM's Articles of Incorporation, the primary objective of such amendments being to seek reclassification under the tax-exempt provisions of the Internal Revenue Code.

Valid proxies from 1,550 members were received and voted in accordance with each member's specifications by Wm. D. Hurst, Donald H. Euler, and Francis T. Colbert. Seven members were present at the meeting to vote in person. The results of this special voting were—

1. Proposal for amendment to Article VI of the Society to provide for Section 501(c)(3) Federal income tax exemption: **For—1,549, Against—8.**
2. Proposal for election of the Society to become subject to the Wyoming Non-profit Corporation Act: **For—1,536, Against—21.**
3. Proposals for amendments to Articles I and IX of the Society to change the name of the Society and to change the corporate seal to provide for the new name: **For—1,185, Against—372.**
4. Proposal to amend Article II of the Society to modernize the objectives for which the Society is formed: **For—1,474, Against—83.**

The officers of the corporation have executed and filed the necessary documents with the Secretary of State of Wyoming for the purpose of effecting the changes voted for by the membership. It is expected that by the time this notice appears in print, such changes will have been made official. Accordingly, the name of the Society hereafter will be **Society for Range Management.** Section letterhead and newsletter heads should be changed to conform with the new name as soon as convenient, but small supplies of old stock may be used up.

In the regular annual election of officers, the following were selected by the membership to serve the Society in 1971 and subsequent years:

President Elect—**Floyd E. Kinsinger.**

Directors—**S. Wesley Hyatt, Bob J. Ragsdale.**

The new officers will assume their posts during the forthcoming annual meeting, at which time Mr. Lorenz F. Bredemeier will be installed as president. Dr. Kinsinger will automatically succeed to the presidency in 1972, while the two new directors will serve for the three-year term 1971–73.

Retiring next month from the Board of Directors will be Past President Donald A. Cox, and Directors Raymond M. Housley and Robert E. Williams. The Society has benefitted greatly from the counsel and direction offered by these three men; they deserve the sincere thanks of everyone.

As soon as practical the Executive Secretary will file with the Internal Revenue Service a petition for reclassification as a "scientific and educational" organization under the provisions of 501(c)(3) of the Internal Revenue Code. While it is hoped that no difficulties will be encountered in obtaining a quick and favorable response from IRS, appeal procedures will be initiated if the reclassification is denied. As explained in the October issue of *Rangeman's News,* we feel that the sought-for classification will, in the long run, prove beneficial to the Society and enable us more effectively to get on with our proper business.

Serving on the 1970 Election Committee and counting the ballots received were F. DeWitt Abbott, Thomas A. Colbert, Thomas K. Eaman, Donald H. Euler, Wm. D. Hurst, George A. Myles, and Francis T. Colbert.

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Abstracts of Papers — Mimeographed abstracts of papers presented at ASRM Annual Meetings for 1962 through 1970. (Separate abstracts for each year.) $1.00 per copy.

All items may be ordered from the Executive Secretary at the above address.

Enclose check or money order payable to ASRM.