JOURNAL OF RANGE MANAGEMENT

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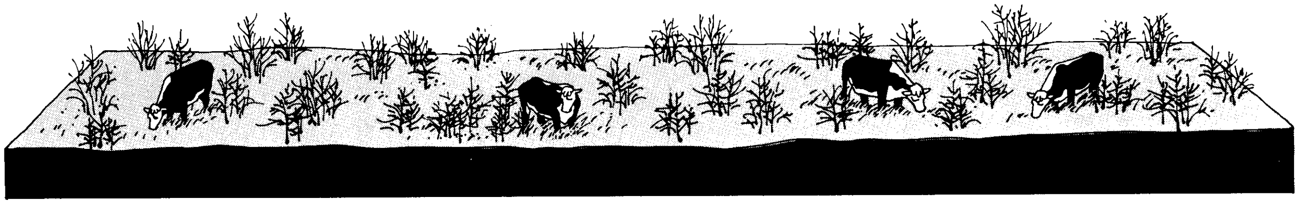
SOCIETY FOR RANGE MANAGEMENT

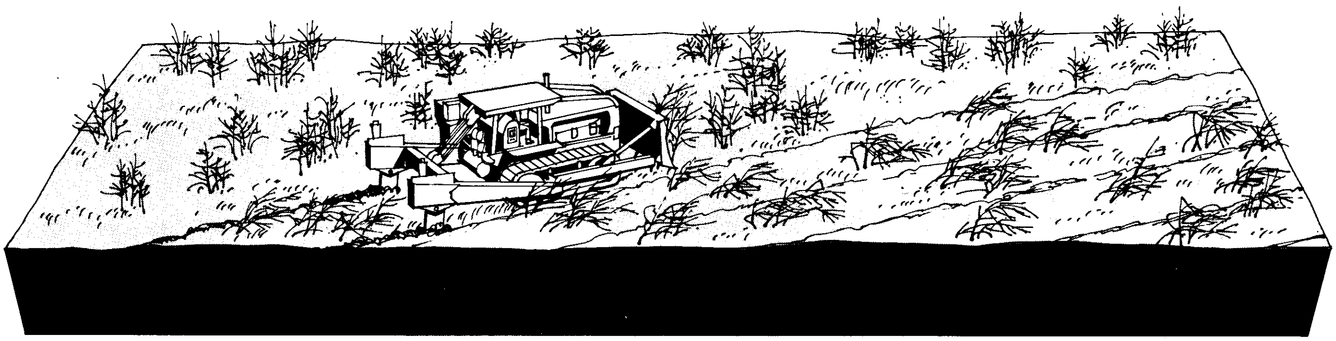
The Society for Range Management recognizes rangeland as a broad category of land, comprising more than 40% of the earth's total land area, which produces a variety of resources beneficial to man.

These resources include both tangible products and intangible values, such as grazeable forage, wildlife habitat, water, natural beauty, recreational opportunities, minerals, some wood products, germ plasm for domestication and breeding, and areas for the study of the ecology of natural systems. The kinds and amounts of resources which may be available from rangeland will vary over time and from one location to another.

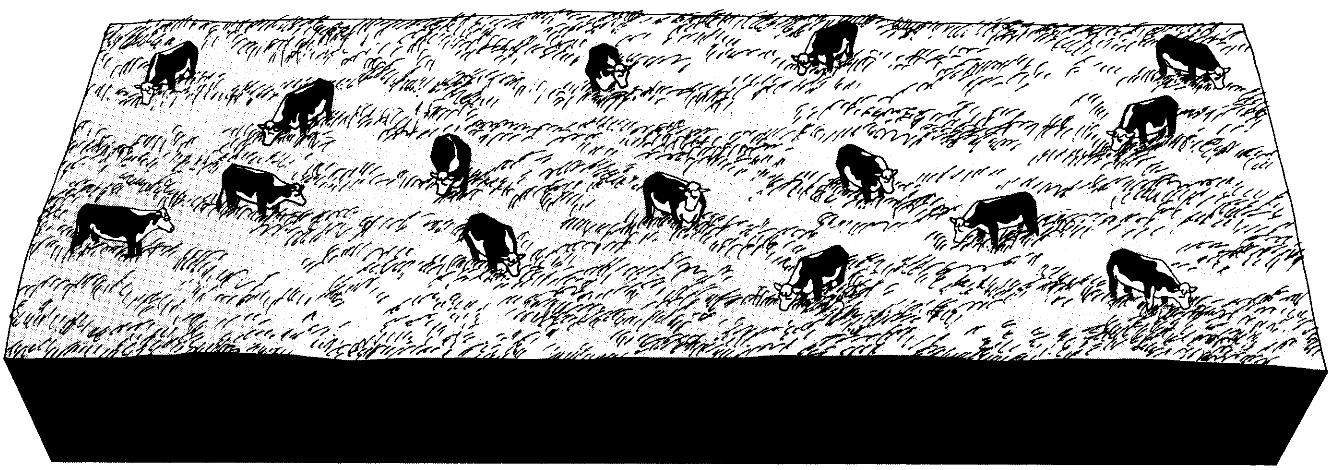
How to make your rangeland greener...



Tear out the brush and reseed. Any stuff growing on your land that won't put weight on a cow is costing you money. And a fast, efficient way of dealing with it is rootplowing. A track-type tractor equipped with a rootplow cuts off the tap roots of the brush below ground to give you an effective kill. It breaks up hoofpan for better water retention, less run-off and a better seed-bed. And it can simultaneously reseed your range as it plows.



Call the land improvement contractor who has Caterpillar equipment. Ask him to look over your range and give you an estimate on what it'll cost to turn your brush into edible grass. You'll find that, because of the efficiency of his Caterpillar equipment, he can keep the lid on costs.



Mechanical brush control can pay for itself. Because you'll be able to graze more cows on your rangeland and their weight gain rates are usually much higher. With your land improvement contractor's methods of mechanical brush control, it won't take long to turn your brushland into grassland.

And boost your profits!

Land investment today builds tomorrow's profits.

CATERPILLAR

Jerry Winfrey, Rising Star, Texas

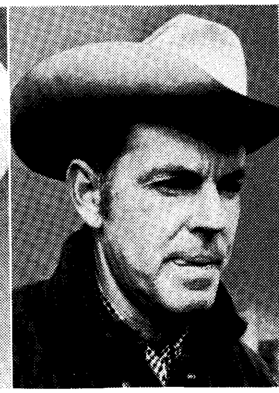
217 steers
Irrigated Coastal Bermuda
2.9 steers per acre, 118 days
A.D.G.—1.59 lb.
545 lb. beef per acre
20.12¢ per pound of gain

Marvin Knopp, Dighton, Kansas

75 steers
Sudan pasture
3-1/2 steers per acre, 90 days
A.D.G.—1.78 lb.
490 lb. beef per acre
11.8¢ per pound of gain

Wendell Kent, Sweetwater, Texas

400 steers
Sudan hay
180 days
A.D.G.—2.25 lb.
12.8¢ per pound of gain



Harry Lynn, South Coffeyville, Oklahoma

701 steers and heifers
Native bluestem range
2.8 acres per steer, 210 days
A.D.G.—1.59 lb.
119 lb. beef per acre
19.38¢ per pound of gain

Joe Ellis, Kaufman, Texas

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Coastal Bermuda
3 steers per acre, 129 days
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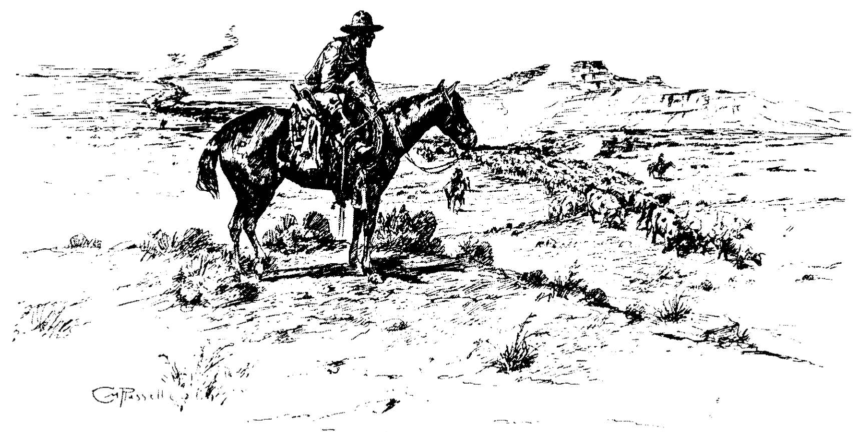
SOCIETY FOR RANGE MANAGEMENT

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



THE TRAIL BOSS

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The objectives for which the corporation is established are:

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

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

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

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

—to promote professional development of its members.

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

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

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ARTICLES

TECHNICAL NOTES

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BOOK REVIEWS

COVER: Range planting methods study on cleared pinyon-juniper sites in north central Arizona (see article by Fred Lavin et al., page 279).

AID's Interest in Range Management and Livestock Production in the Tropics and Subtropics

OMER J. KELLEY

Highlight: *Grassland resources in the tropics and subtropics of South America, Asia, and Africa occupy nearly one billion hectares of land, roughly twice as great as all arable lands in these areas. These support about four billion sheep units of ruminant livestock. One major hope for more nearly meeting animal protein needs for peoples of the tropics and subtropics is by increasing supplies of meat from ruminants grown on permanent grasslands in four ecological zones—humid tropics, savannas, sahelians, and semidesert. The five major categories of limiting factors that control progress in livestock production on rangelands are (1) feed supplies and animal nutrition, (2) animal disease control and prevention, (3) livestock husbandry and management, (4) animal breeding, and (5) efficient marketing systems. A "Range Code," consisting of 12 principles, is presented to evaluate similarities and differences between the tropics and temperate zones. Group action by "associations" of pastoral groups is suggested as a method of improving the potential for more efficient livestock production and marketing without disturbing private ownership of livestock.*

The author is director, Office of Agriculture, Bureau for Technical Assistance, U.S. Agency for International Development, Washington, D.C.

Paper presented at the 26th Annual Meeting, Society for Range Management, February 8, 1973, Boise, Idaho.

The levels of productivity achieved on rangelands in the United States and in Australia might properly be regarded as goals to be achieved on the rangelands of the tropics and subtropics. At present, the rangelands of Africa, the Middle East, and South America are badly degraded as to soils and vegetation and are low in producitivity of livestock. Practical methods of improvement have thus far largely escaped the efforts of external assistance agencies from the developed countries who have attempted to work effectively in many of the 60 less-developed nations. However, the problems and effective procedures are coming more clearly into focus, and the prospects for real progress appear to be definitely improving. Those with foreign experience in the tropics and subtropics can attest to the soundness of many basic principles of range management as developed in the U.S., as well as the marked differences in application of these principles to rangelands in tropical regions.

"Permanent grasslands of all ecological zones in the tropics and subtropics occupy nearly one billion hectares of land, roughly twice as much as all arable lands."

Magnitude of Grassland Resources of the Tropics and Subtropics

In the decade of the 1960's, foreign assistance to less developed countries emphasized food production to combat recurring famines, to improve human nutrition, and to keep pace with rapidly growing populations. It has become steadily clearer that the permanent native grasslands of these countries also must be more effectively utilized if these countries are to achieve desirable development. Permanent grasslands of all ecological zones in the tropics and subtropics occupy nearly one billion hectares of land, roughly twice as much as all arable lands (Table 1). Since ruminant livestock constitute the principal means of utilizing grazing lands for human support, it is noteworthy that the total ruminant livestock populations in the 60 less-developed nations amount to about 4 billion "sheep units." (One cow or buffalo = five sheep; and one goat = one sheep. Sheep are the most universal type of ruminant grazed on tropical grasslands, although cattle predominate in many regions.)

Unfortunately, the current productivity of these herds and flocks is rarely more than one-fourth as high as that realized from livestock on U.S. rangelands. This is highly significant since these livestock constitute a major source of animal proteins for human diets in these countries, and present levels of animal protein intake are very low. In general, proteins of plant origin are deficient in one or more of four amino acids that are essential for human nutrition (lysine, methionine, threonine, tryptophan); and animal proteins are required to balance amino acid needs. Peoples of less-developed countries are subsisting on diets that are not only low in total protein, but these diets contain less than half the animal proteins consumed per capita in western Europe and North America. One major hope for more nearly meeting animal protein needs for peoples of the tropics and subtropics is by increasing supplies of meat from ruminants grown on permanent grasslands.

Aside from the urgent need to improve protein components of diets within each country, there is a great and growing demand for meats in countries that are seeking imports, including Japan, the oil rich countries of the Middle East and North Africa, Western Europe, and North America. The less developed countries need to earn foreign exchange, and meat exports are a prime commodity for such trade. To fully exploit this opportunity, there must be greatly improved efficiency in meat production and adequate sanitary precautions to avoid dissemination of animal diseases.

Table 1. Native grassland[1] and ruminant livestock populations[2] of the tropics and subtropics.

Item	South America[3]	Asia[3]	Africa[3]	Total
Permanent native grasslands				
Grasslands (million ha)	189	167	612	968
Arable (million ha)	47	301	157	505
Livestock (million animals)				
Cattle	190	279	143	612
Sheep and goats	154	340	256	750
Buffalo and camels	–	91	10	101
Total sheep unit equivalents[4]	1,104	2,190	1,021	4,315

[1] Includes grasslands of savanna, sahelian, and semidesert ecological provinces, and nonarable lands of humid tropics.
[2] Believed to be supported largely on permanent grasslands. Ruminant livestock constitute the principal means of utilizing grazing lands for human support.
[3] South America includes 8 tropical countries; Asia includes 19 tropical and subtropical countries, excluding Mainland China; and Africa includes 33 tropical and subtropical countries.
[4] One cow or buffalo = 5 sheep; 1 goat = 1 sheep.

Ecological Zones

The major resources for expanded meat production are the permanent grasslands of the tropics and subtropics. These occur in four major ecological zones, and management of grasslands and livestock should be adjusted to the conditions in each zone, as well as to the peoples and livestock now present. Some dominant features of each zone should be noted.

The Humid Tropics

The humid tropics have an average rainfall of 40 to 80 inches, with relatively short dry seasons not exceeding 3 months. These lands have been cleared of forest, and crops are grown on arable soils. Native grass occupies lands that are too steep and erosive, or have shallow soils, or are stony, poorly drained, or otherwise nonarable. These lands are grazed by communal herds and flocks, in which individual animals are personally owned by villagers but have unlimited access to the grazing lands. Each farmer uses his animals to consume his crop wastes (stalks, straw, vines, etc.), but there is little or no production of seeded forages to support livestock. In general, these communal grazing lands are overstocked, and no regulated use or improvement is practiced.

The humid tropical regions offer very great opportunities for improved feed production, that should include the introduction of improved grasses and legumes into the communal grazing lands and more appropriate management of the grazing herds. An even greater opportunity is the inclusion of forage plantings in crop rotations on arable lands. It is becoming apparent that sustained land productivity for crops will require such forages in the rotations on arable soils, and the effective use of forages will lift livestock enterprises from the present role of scavengers to a major source of foodstuffs and of cash income. These apparent opportunities have yet to be exploited. However, we do have information on about two dozen superior tropical forage grasses and about a dozen adapted forage legumes. Within a considerable number of these species, there are improved varieties for which seed is available. Australia and Brazil have been leaders in identifying productive forage grasses and legumes and in using these to support livestock enterprises. In many other countries, there has been some field evaluation of promising species so that some basic information is available. The development of practical systems of livestock production based on seeded forages is still in very early stages or is nonexistent.

Savanna and Sahelian Zones

The savanna and sahelian zones have 20 to 40 inches annual rainfall, and the dry season may extend from 3 to about 8 months. The sahelian zone is the less humid sector of these permanent native grasslands, somewhat comparable to the steppe lands of temperate zones; but low woody species are present in considerable abundance, with intermingled grass and herbaceous growth. Crops are grown extensively in these ecological zones, but are confined largely to soils that are permeable, fairly deep, and comparatively fertile. The lands not arable and native grasslands vary greatly from region to region. In some regions the lands are largely cropped; but in others cropping is restricted to certain favorable soils and all other lands are grazed.

In these regions it is traditional that there are two separate types of agriculture: the *roving herdsmen*, who own their flocks and herds and use all grazing lands jointly, and the *settled farmers* living in villages, who are primarily crop producers. While there is some inter-relationship between the two types of culture, the concept of integrated systems of agriculture, employing both crops and livestock enterprises for their mutual support to increase incomes and to reduce the hazards from unpredictable droughts, is hardly ever employed.

It is in these regions that many abortive efforts have been made by governments, with respect to grazing lands and herdsmen. These efforts have ranged from social and political programs to "settle the nomads," to urban oriented programs designed to force herdsmen to move animals to market for sale at low prices to benefit urban poor people who need meat. In fact, the exploitation of dry rangelands requires the type of roving herdsmen that are now present, and direct assistance for improving range management and livestock production should be fruitful. The integration of livestock and cropping enterprises into combined systems will also require expanding the present cropping systems to include forage production and livestock. Fortunately, we have some of the basic components fairly well identified, such as the improved forage species for both seeded plantings and for range improvement and the basic principles of range management that are largely borrowed from the U.S. range industry.

Semidesert Zone

The semidesert zone has less than 20 inches natural rainfall; the vegetative cover is sparse but contains appreciable amounts of grass and other palatable forages intermingled with unpalatable short woody plants. The roving herdsmen and their livestock occupying these zones are skilled in survival under existing conditions, and they must be used effectively to improve productivity of these lands.

"While concern is sometimes expressed about the encroachment of useless deserts onto rangelands, this concern has not been translated into effective programs."

Except perhaps in a few parts of the Middle East, nothing much has been done to actually apply basic principles of range management and of modern technology to improving semidesert rangelands. While concern is sometimes expressed about the encroachment of useless deserts onto rangelands, this concern has not been translated into effective programs. When serious attention and appropriate resources are directed toward restoration and development of all rangelands, the vast expanses of semidesert ranges in the tropics and subtropics on all continents must receive attention. This is needed to more fully utilize potential resources for national development and to make available to the hardy roving herdsman the improvement in the quality of his living that seems feasible and economically sound.

The Range Code

It may be useful to examine the factors that seem to control progress in livestock production on rangelands of the tropics and subtropics. The five major categories of *limiting factors* are:

a) feed supplies and animal nutrition
b) animal disease control and prevention
c) livestock husbandry and management, including water supplies
d) animal breeding (improvement)
e) efficient marketing systems.

The most significant principle that applies to less developed countries is that *all* of these possible limiting factors must be dealt with *simultaneously* to make progress. There are many instances where creditable progress has been made with one or more of the categories, but with no visible effect on the end product because some other factor was limiting final productivity. By contrast, in developed regions the more advanced status of range management and the livestock industry makes it possible to deal with one or two limiting factors and to expect prompt benefits when these limitations are reduced. It is proving difficult to convince administrators and other decision makers who become concerned with improving livestock production on rangelands that research must deal simultaneously with multiple limiting factors, and that improved production systems must be similarly balanced to produce significant benefits. As range specialists well realize, livestock production on rangelands is as complex as the entire gamut of crop production; and while research may explore individual facets one by one, the results must be combined into a functional system for the livestock producer. This is true in the tropics, with the additional qualification that the system must be made understandable to the herdsman (or farmer) and be within his capabilities when supported by technical guidance and supporting resources. It is good to remember that the herdsman (Bedouin, nomad, or any other name) is a *specialist in survival* under the conditions he knows and will accept change only when convinced that the apparent benefits far exceed the hazards and penalties of failure with new ideas.

Perhaps the best way to evaluate the similarities and the differences between the tropics and the temperate zones is to consider each of the 12 principles that constitute the "Range Code."[1]

1. Adjust Livestock Numbers to Forage Supplies

This implies use of all available forage to supply feed for the entire year, but it also implies reduction of livestock numbers to stay within predictable feed supplies. With the prevalent custom of nearly complete separation of herdsmen from farmers in tropical regions, complete dependence is placed on rangelands, which seems to be an unnecessary constraint except in drier regions where forage production on arable lands is not feasible. The common practice of using live animals as the resource reserves to tide over disastrous droughts, disease epidemics, or to meet other needs, means that the herdsman is unwilling to cull his herd. He continues to keep nearly all males (uncastrated), as well as other unproductive animals, using up precious feed and water. However, it is becoming apparent that the herdsman will sell stock if he can be assured of a fair price and if he can place such income in a safe and easily accessible repository.

It should be possible to introduce the practice of grazing not more than 60% of the forage produced each year, thus opening the door for range improvement. When practical methods of providing additional forage from arable lands are developed, he will have an additional margin of flexibility.

2. Practice Periodic Grazing and Resting of Range Areas

While this principle appears impossible to implement when

[1]The "Range Code" is an arbitrary listing of basic principles of range management and livestock production. It is useful in visualizing range management as an autonomous system.

all rangelands are open to every herdsman, with no regulation, there are hopeful signs. For example, in the Masai tribal regions of East Africa, progress has been made in designating rather large range areas as being predominantly the province of specific tribal groups, even though these groups do not own the land. Also, in Moslem countries there is an Islamic dictum that certain range areas may be designated by the Emir (or comparable ruler) as reserves that are to be grazed only in times of necessity. While the royal decree covering this practice has had various interpretations, this Islamic tradition could be used quite effectively in providing reserve supplies of feed and in achieving range restoration.

"Tropical and subtropical rangeland appear to be degrading at an alarming rate. . . ."

3. Suppress Undesired Vegetation

Tropical and subtropical rangelands appear to be degrading at an alarming rate by encroachment of woody and unpalatable plants and by reduction of forage grasses, legumes, and other edible species. Overgrazing, which is a prime causal factor, continues, and comparatively little has been done to control unwanted vegetation by use of herbicides or by mechanical means. Some attempts in brush suppression have not been accompanied by other necessary management practices to achieve range restoration and were not continued. Yearly indiscriminate burning, widely practiced, has done much harm, but is continued because of the more nutritious forage available for a short period when rains occur, coming at the end of a dry season when stock are in a desperate, starved condition.

4. Introduce and Establish Superior Grasses and Legumes

Information and materials are accumulating to implement this principle, when companion practices are involved. There are five grasses and two legumes recognized as being adapted to semiarid zones, 10 grasses and five legumes for savanna and sahelian zones, and 12 grasses and 10 legumes for wet/dry tropical zones with long dry seasons. The practices likely to be successful for specific soil families, under regulated range use, remain to be worked out in most cases.

5. Use Controlled Burning as a Management Practice

It will be difficult to convince herdsmen that burning must be controlled for use as a range improvement practice when they have come to regard it as a rescue operation for starving livestock. Control of burning to have maximum effect on suppression of brush and inedible plants and to provide opportunity for introduction of improved forage species will certainly have to be demonstrated under field conditions and be supported by government actions to become widely adopted. Adoption of other practices—elimination of overgrazing, culling of excess animals, reservation of range areas for feed in critical periods, and other means to prevent chronic starvation—should simplify the problem of getting herdsmen to accept controlled burning.

6. Improve Soil Storage of Rainfall

Since moisture supply is a major ecological factor on all subhumid rangelands (in fact, on all grasslands with a dry season of 2 months or longer) prime attention should be given to improving infiltration rates and storage of rainfall in the soil profile. Forage grasses and legumes have a positive effect on soil moisture storage; brush and trees are detrimental. Thus, controlled grazing to improve grass cover and successful reseeding with adapted forage species should be important practices in range restoration. The fibrous roots of grasses, regenerated yearly, and the deep penetration of legume tap roots tend to progressively improve the soil's capacity to receive and store rainfall, with beneficial effects on feed production.

Water spreading is a practice that may have an important role where the topography is favorable, particularly in the drier regions. It should not be ignored in semidesert regions, even though there may be scant vegetative cover on the smooth areas to which water is led. Bulrush millet (pearl millet) is an excellent tropical forage species to plant on new areas where water spreading is to be practiced, until such time as perennial species can be established.

7. Provide Stock Water to Serve Forage Growing Areas

The availability of stock water supplies within a few hours' walk is important in drier regions. As the dry season progresses, herdsmen take their flocks to scanty feed sources that are more and more distant from water. Stock that are grazed more than one day's walk for the livestock are under severe stress, and the animals become quite desperate when watered only once in two or three days. Survival, rather than production, becomes the dominant consideration. The stress of aggravated thirst is most serious for the breeding herd and younger animals, and this affects the reproduction and growth rates.

Herdsmen badly need the assistance of governments in developing water resources through construction of ponds to impound runoff, wells to exploit subsurface aquifers, or cisterns in the dry washes of semiarid regions. Very little attention has been given by governments to the discovery and development of stock water supplies to permit exploitation of forage in dry seasons. AID has made some successful efforts in this direction, but this assistance will be most effective as a component of a complete range management system.

8. Protect Breeding Herds from Under-nutrition and Malnutrition

Despite the general knowledge that forage becomes steadily less nutritious as the dry season continues, little has been done to cope with this problem. Herdsmen (and others) do not realize that the energy in low-protein, fibrous forage, is incompletely used when protein falls to such low levels as 6%. Maintenance of body weight declines, and growth and reproduction come to a halt. This is one factor that would be promptly alleviated if harvested forage on arable land could be utilized to improve protein and mineral intake of animals otherwise subsisting on low-grade roughage. For example, the possibility of using oil seed cake (often wasted or sold for low prices) as a high protein supplement will become more feasible when integrated crops/livestock systems are practiced, and livestock become an important cash "crop."

Under-nutrition can be alleviated by controlled stocking rates, use of rangelands held in reserve for dry seasons, and by use of forage from arable lands. To the extent that legumes are present in such forages, they should combat protein malnutrition. These opportunities are rarely being exploited in the tropics and subtropics. We believe the situation will soon change in Latin America, where the collection, collation, and interpretation of all available feed composition data by the University of Florida under an AID contract now provides exceedingly useful data on the nutritive value of native feeds. Livestock specialists in many Latin American nations are enthusiastically participating in this program, and this movement should have a profound effect on livestock production on grasslands. This activity should be extended to Africa and Asia.

9. Practice Systematic Animal Health Control Measures

The catastrophic effect of uncontrolled disease is known to most herdsmen. They also are aware that diseases such as rinderpest can be controlled by vaccination, and there is little or no resistance to the whole range of health control measures that may be undertaken. These herdsmen are completely dependent on external assistance for effective animal health control measures. Controlling ticks by regular schedules of dipping has been promptly adopted by the Masai tribes in Tanzania and Kenya as soon as the facilities and technicians were available. It should be recognized that diseases of all types and ecto- and endoparasites may flourish throughout the year in the tropics and subtropics, so that animal health programs have greater urgency in these warm regions than in the temperate zones.

Probably the greatest weakness on the part of governments has been lack of understanding that control of a serious disease, such as rinderpest, produces little effect on overall livestock production unless all other major constraints are dealt with simultaneously. This is the reason for discouragement with disease control programs, resulting in reduction of budgets and disillusionment as to the future of the livestock industry.

10. Reconcile Competitive Demands for Milk to Meet Home Needs and to Raise Calves

This is a serious problem in most herdsmen's flocks and herds because of the crucial role of milk in meeting family needs. This problem is not so acute for crop farmers who also have some livestock, but the herdsman who derives the majority of his foodstuffs from his animals as milk and meat (and blood in many African regions) has daily needs for milk. The calves (lambs or kids) are dependent on the same supply of milk for survival and growth. Since indigenous animals, under range conditions, produce low volumes of milk and lactation periods are short, there is insufficient milk for the calf and for family use. Usually, the calf is progressively deprived as the dry season progresses and the supply and quality of feed decreases. The end result is a stunted calf or failure to survive. The maintenance of a herd of strong animals is nearly impossible when regeneration is largely dependent on stunted calves.

This problem could be reduced if cows were bred to freshen at the flush period of forage growth, following onset of rains, so that milk flow would be continued for a longer period and both calf and family would be more nearly satisfied. Even that system fails to provide continuing milk flow in dry seasons. Milk flow on a year-round basis is feasible only if adequate feed and water are available throughout the year.

11. Undertake a Sound Program for Livestock Improvement

There has been a strong belief by livestock specialists in the western world that indigenous livestock of the tropics are lacking in hereditary traits needed for a strong livestock industry. This has led to efforts to make giant strides in herd improvement by importing exotic types and breeds of livestock from temperate zones. This has not led to the anticipated benefits, since the exotic stock are usually poorly adapted to hot climates, lack resistance to endemic diseases and parasites, and are poorly suited to the acquisition and conversion of local forages for nutritional needs. Serious efforts should be made to selectively increasing the productivity of indigenous types and breeds, rather than attempting to by-pass the basic genetic factors of production by importing exotic germ plasm or semen from such animals in the hope of instant improvement. Imports of tropical breeds from other similar regions may have practical value for herd improvement to be practiced by herdsmen. It is well known that the development of new breeds from crosses of widely different types requires large animal populations and sustained control of selection over six to ten animal generations. This type of animal breeding by hybridization with exotic breeds requires stable and sustained allocation of resources and the direction of competent animal geneticists supported by other specialists in animal nutrition, animal health, and animal husbandry.

There is a very real need for the improvement of indigenous breeds that is well within the resources of every developing country. Most herdsmen are aware of the superior attributes of some members of the herd or flock (a traditional awareness going back at least to the times of Jacob), but little use has been made of this knowledge for herd improvement. However, the possibility of significant selection and propagation of desirable traits should be greatly improved as supplies of feed and water become more stable and enlightened management of the herd results in stronger and earlier maturing breeding stock. Reduced mortality and larger calf crops also will give the breeder a greater opportunity to select animals that appear to have superior inheritance, as distinguished by escape and survival from all of the prevalent hazards that otherwise afflict livestock production.

In a herd of cattle with stabilized production, one healthy bull should be capable of serving 20 to 25 cows. All other males should be removed from the breeding herd. Selection of bulls with desirable conformation, which are the offspring of productive cows, is a particularly effective method of herd improvement, since each such bull imparts his inheritance to all the calves he sires. When the choice of bulls is accompanied by selection of the better cows for his service, genuine improvement in each successive animal generation becomes possible. This method is applicable also to buffaloes, sheep, and goats.

12. Establish a Program for Timely and Orderly Marketing of Livestock

This is actually a complex of many factors, including transportation of livestock to markets, setting up classes and standards for establishing market values, equitable pricing to the herdsmen, slaughter and processing, and efficient movement of meat to the ultimate consumer. There are other factors also, such as safe repositories made available to the herdsmen when he sells his animals, that is, even more

acceptable to him than holding his animals alive in his own herd to meet his subsistence needs. He is not likely to market all excess males (sometimes 50% of his herd), as well as barren females, when they serve as capital reserves with which he is able to survive in terms of adversity.

Extensive studies have been made by AID, FAO, and other agencies on livestock marketing without sufficiently relating the marketing function to the production aspect of the industry and the needs of the herdsman, who is intent on survival and protection of his family. Marketing is a prime factor, but it does not stand alone. Marketing must be considered as part of the system of livestock production. It will not do to attempt to influence marketing solely for the benefit of the urban population that needs meat. The livestock belong to the herdsman and are managed by him. Improved production programs must be aware of the role of natural resources in country development and the herdsmen's use of these, accompanied by an efficient marketing system.

Group Action to Make Range Improvement Possible

This is a unique problem of most developing countries, where grazing lands are not owned by the herdsmen and are not fenced. The animals used to graze these lands are owned by individuals or family groups, but are grazed in communal flocks and herds on open grazing lands. In general, there is no limit to the number of animals that each owner contributes to the communal grazing group. Also, there is no effective restriction on the use of rangelands and other permanent grasslands by herds and flocks of other communal groups, except those of ill-defined tradition.

Under these conditions, there is no inducement for undertaking such practices as control of stocking rates, rotation or deferred grazing, the establishment of feed reserves, suppression of brush, or other range improvement practices. Neither is it feasible to undertake development of stock water supplies, herd improvement, or other practices that involve management of total populations of livestock.

To make possible effective programs for improving livestock production on rangelands, it is necessary to have acceptable allocations of range areas to specific groups of livestock producers, even though such allocations do not convey actual title to the land. When exclusive allocations of rangelands are made to the pastoral groups traditionally associated with these lands, or to other groupings that are identified, there is then an inducement to the users to undertake sustained range protection and improvement and the associated livestock management practices. The designated group can then take collective action to improve production with the expectation of reaping the rewards or of paying the penalty in reduced productivity for not undertaking appropriate action.

The mechanism of forming self-governing "associations" made up of livestock producers in a specified region and of making governmental technical assistance available to such associations is a promising approach. Such group actions should improve the potential for more efficient production and marketing without disturbing private ownership of livestock.

Livestock Grazing on Public Lands: Unity for Political, Economic, and Ecological Reasons

GERALD W. THOMAS

Highlight: *The increased pressure on public lands due to conflicting interests, combined with the increased concern on the part of each individual for the environment, makes it imperative that each land use alternative be carefully examined. Decisions on land use must take into consideration the economic importance of the ranching industry to the nation, the social and political climate of the times, and most importantly, sound ecological principles. A careful examination of long-range research can only lead to the conclusion that: (1) on vast areas of public lands, livestock grazing, under proper management, is compatible with other uses, (2) on a limited number of sites, grazing by domestic livestock is detrimental to the resources and competitive with other uses, and (3) on other sites, grazing by livestock can be the most beneficial use to society for economic, social, and ecological reasons.*

It is inevitable that pressure on the public land base in the United States will increase as the numbers of people increase. Also, it is inevitable that each person will have more impact on the land and more concern for land use as our level of living improves, as we become more mobile and able to travel, as we build into our schedules more leisure time for outdoor recreation, and as we become better informed about ecology and the environment. This increased pressure on public lands coupled with the increased concern on the part of each individual will generate more and more conflicting interests—more problems in land management and land use.

It would be foolish to assume that an easy solution to these conflicts will be forthcoming. There is no single solution that will satisfy all interest groups. Rather, there are several alternatives, and each alternative will require some compromise between livestock, wildlife, forest, watershed, mining, recreational, and other interests.

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Economic Considerations

In 1972, there were nearly 118 million head of cattle and 18.5 million head of sheep in the United States (Table 1). The 17 western states contained 61 million cattle and about 15 million sheep. The inventory value of these cattle and sheep was about \$12.9 billion, while the gross annual income is about \$9.5 billion.

Dr. James R. Gray, New Mexico State University, says that it is safe to use 2.86 as a multiplier factor for range livestock. This means that the annual contribution of the industry as we proceed from the supplier through the producer and on to the consumer in the 17 western states would be about \$27 billion. This is a big and important business for this country.

The U. S. Forest Service now issues grazing permits in the 17 western states for about 1.5 million cattle and horses and 2 million head of sheep and goats (Table 2). The Federal government owns and administers approximately 273 million acres on which grazing is allowed (Public Land Law Review Commission, 1970).

Table 1. Number (1,000), inventory value ($1,000), and gross income ($1,000) from cattle and sheep in the United States, 1971-1972.[1]

Area	Cattle			Sheep		
	Number Jan. 1, 1972 (1,000 head)	Inventory Value 1972 ($1,000)	Gross Income 1971 ($1,000)	Number Jan. 1, 1972 (1,000 head)	Inventory Value 1972 ($1,000)	Gross Income 1971 ($1,000)
11 Western States	22,191	4,747,840	3,753,410	8,795	226,049	156,881
17 Western States	61,319	12,503,301	9,261,595	14.640	347,103	243,757
United States	117,916	24,616,530	15,230,924	18,482	423,531	318,979

[1] Sources: "Cattle, Sheep and Goat Inventory," Crop and Livestock Reporting Board Lv. Gr. 1 (72), SRS, U.S. Dep. Agr., Washington, D.C., February 4, 1972, 16 p., and "Meat Animals, Farm Production and Income," Crop Reporting Board MtAn 1-1 (72), SRS, U.S. Dep. Agr., Washington, D.C., April 1972, 15 p.

Of course, most of us realize that this major grazing area is in the 11 contiguous western states where Federal land comprises a range of 86% of the total area of Nevada to 29% of the land area in the State of Washington. The Public Land Law Review Commission Report shows 64% of Idaho as Federal lands, which contribute 17% of the total forage consumed in the state. In a study by Neilson and Workman (1971) in Utah, the statement is made that, "about 36% of all federal land is grazed by livestock, and about 73% of the federal land that is grazed is located in the 11 western states." The Public Land Law Review Commission Report states: "We have recognized the dominant role of Federal public land in the 12 far Western states. In large measure the future of those states may depend on the adoption of sound public land laws and policies. . . ." Certainly, grazing on public lands is highly significant to the economy and well-being of the West as well as to the nation as a whole.

I am concerned about the lack of knowledge of the economic facts of life that is prevalent in certain segments of today's society. Some people seem to forget that the government runs on tax dollars—not welfare programs. People also forget that our international balance of payments is now highly dependent upon the sale of agricultural products abroad.

Yet, it appears that many of our actions tend to hamper the growth and development of the agricultural industry. Before we prohibit livestock grazing on public lands, let's re-examine the role of the industry in our economy. Unity of purpose and effort, through the Society for Range Management, can lead to more careful economic analyses and more balanced action programs.

Political and Social Considerations

I would like to preface my discussion of social and political considerations relating to public land use by the presentation of a philosophical principle. Since I'm not sure who deserves the complete credit for this concept, I am going to call this the "Thomas Principle (more or less)." It compares, in its sweeping implications to the Peter Principle and Parkinson's Law. It goes something like this:

> Traditional heroes can become overnight villains with a change in the attitudes of people or the laws of the land.

I'm quite sure this principle is not original. Seems like I've heard something somewhat like this somewhere before. Therefore, when you pass this on to your friends, be sure to include the parenthesis (more or less) with the citation. Let me illustrate this principle with a review of history. The people of America have gone

Table 2. Number of animals grazing lands administered by the Forest Service and Bureau of Land Management in the 11 and 17 Western States 1970-71.[1,2]

State	Forest Service		Bureau of Land Management[3]		Total	
	Cattle and horses	Sheep and goats	Cattle and horses	Sheep and goats	Cattle and horses	Sheep and goats
Arizona	158,219	58,547	224,924	28,530	383,143	87,077
California	126,725	79,594	131,981	260,901	258,706	340,495
Colorado	204,330	384,217	594,255	851,609	798,585	1,235,826
Idaho	138,808	446,728	576,050	1,326,159	714,858	1,772,887
Montana	114,798	99,711	615,201	369,722	729,999	469,433
Nevada	62,350	105,236	356,040	406,416	418,390	511,652
New Mexico	105,703	43,072	264,307	211,592	370,010	254,664
Oregon	124,805	66,626	278,356	64,437	403,161	131,063
Utah	118,634	382,766	173,454	1,047,603	292,088	1,430,369
Washington	39,940	11,374	11,200	8,800	51,140	20,174
Wyoming	147,681	347,737	721,866	1,412,559	869,547	1,760,296
11 states	1,341,993	2,025,608	3,947,634	5,988,328	5,289,627	8,013,936
Kansas	111	0	1,800	0	1,911	0
Nebraska	22,159	1,350	10,500	100	32,659	1,450
North Dakota	77,733	1,400	8,200	5,200	85,933	6,600
Oklahoma	5,728	0	0	0	5,728	0
South Dakota	80,638	10,719	9,400	24,200	90,038	34,919
Texas	12,093	0	0	0	12,093	0
17 states	1,540,455	2,039,077	3,977,534	6,017,828	5,517,989	8,056,905
United States	1,582,630	2,039,876	3,977,589	6,034,628	5,560,219	8,074,504

[1] Data for the Forest Service is 1971, for the Bureau of Land Management is 1970, both being the latest available.
[2] Sources: "Agricultural Statistics 1972," U.S. Dep. Agr., Washington, D.C., 1972, and "Public Land Statistics," Bureau of Land Management, U.S. Dep. Int., Washington, D.C., 1972.
[3] Includes both grazing district and estimate of livestock using leased lands.

through several stages in the development of attitudes and policies relating to public land use. In the early years of our history, the major policy and practice was toward settlement of the West—to *utilize* and *exploit* the vast and "unlimited" land, forest, and range resources. The headlong dash toward the Pacific was encouraged by the passage of the Homestead Act in 1862, the Desert Land Act in 1877, the Enlarged Homestead Act in 1909, and other legislation to encourage land settlement by individuals. Large Federal land grants were also made to railroads and to the states for educational purposes.

As the frontiersman reached the Pacific Coast—and settled much of the better land in the central United States—it became apparent that the forest, farm, and range resources were not "unlimited" as visualized during the colonial period. There began, therefore, a period of increasing concern about relentless exploitation. New concepts of conservation were promoted. National Parks were established. Forest Reserves were set aside. As attitudes of people changed, new laws were passed. The pioneer frontiersman and the Paul Bunyan heroes of the lumber industry became the culprits who were exploiting our natural resources. The Thomas Principle (more or less) was at work.

Out on the range the Indian wars were replaced by conflicts between cowboys and sheepherders—between stockmen and sodbusters. Barbed wire became both one tool of conflict and one means of compromise. On Dec. 29, 1904, the newspaper *Morning Oregonian* carried a letter to the editor which read in part (Neilson and Workman, 1971):

Mr. Editor: Seeing that you are giving quite a bit of publicity to the Sheep Shooters of Crook County, I thought I would lend you some assistance by giving you a short synopsis of the proceedings of the organization during the past year—

I am authorized by the association (The inland Sheep Shooters) to notify the Oregonian to desist from publishing matter derogatory to the reputation of the sheep shooters of Eastern Oregon . . . . We would thank the Oregonian and the Governor to attend strictly to their business and not meddle with the settlement of the range question in our province.

We are the direct and effective means of controlling the range in our jurisdiction. If we want more range we simply fence it in and live up to the maxim of the Golden Rule that possession represents nine points of the law. If fencing is too expensive, substitutes are readily manufactured. When sheepmen fail to observe these peaceable obstructions, we delegate a committee to notify offenders . . . and being men of high ideals as well as good shots by moonlight, they promptly enforce the edicts of the Association. Our annual report shows that we have slaughtered between 8,000 and 10,000 head of sheep during the last shooting season and we expect to increase this respectable showing during the next season providing the sheep hold out and the Governor and the Oregonian observe the customary laws of neutrality . . . .

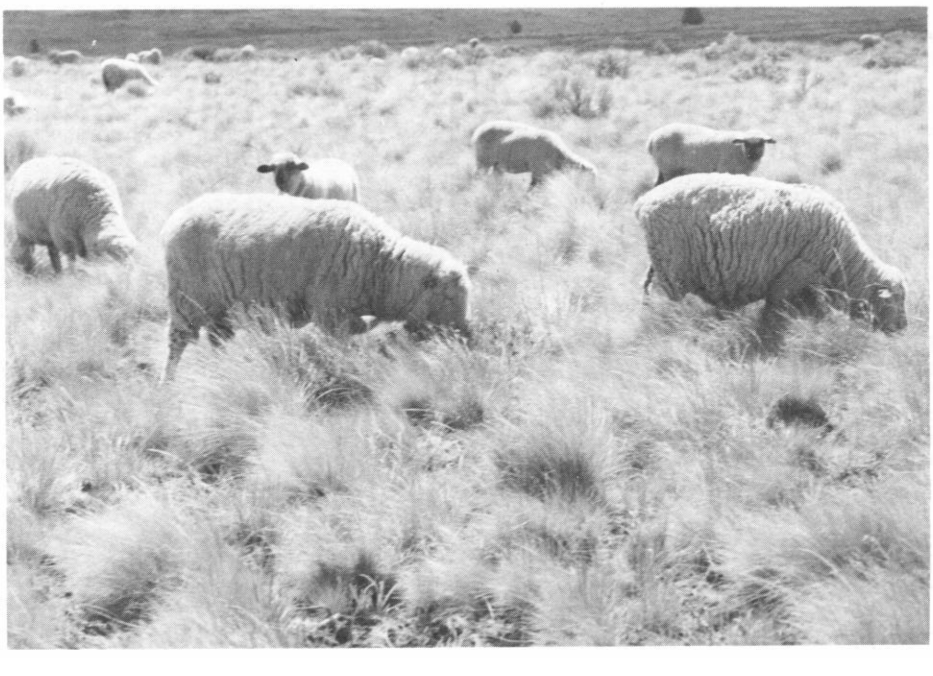
(Signed) Corresponding Secretary
Crook County's Sheep Shooting
Association of Eastern Oregon

Conflicts between the cowboys and sheepherders soon became insignificant as government moved in to control the public lands. The new hero was the independent rancher—either a cowman or a sheepman who could stand up to the forest ranger. The Thomas Principle (more or less) was still at work. But, I agree with Dr. Marion Clawson when he stated, "As a nation, we were extremely fortunate in the caliber of our public land managers" (Clawson, undated).

With the onset of the Great Depression and the Dust Bowl, some historians say we entered the "golden years of conservation" in the United States (Colorado Forest Industries Committee, 1965). Under Franklin Roosevelt's administration significant conservation legislation was enacted—including the establishment of the Soil Conservation Service, the TVA, the Civilian Conservation Corps, and the Resettlement Administration; finally, the era of the "free range" ended with the passage of the Taylor Grazing Act in 1934. I well remember from my ranch background on Medicine Lodge that these were sad days for many ranchers as they saw the Wild West changed and many of their ranching enterprises virtually crumble. The evangelistic approaches of such dedicated individuals as Forest Service Chief Gifford Pinchot and SCS Chief Hugh Hammond Bennett began to have an impact on land-use policies. But conservation was still an uphill battle.

In the political arena we have seen different individuals and groups emerge as the proponents of various policies on public lands. In the 30's, 40's, and 50's, Federal land agencies and their technical personnel were face to face with the ranchers on specific controversial issues. Hard feelings were common. Heroes and villains were identified by the laws and the attitudes of people. The Thomas Principle (more or less) was still functioning.

Bureaucracies continued to grow. The political strength of the farm and ranch sector dwindled. Total number of farms and ranches peaked out in 1935 at 6.8 million. From this high point the number of farms and ranches dropped to the present level of just under 3 million. As the shift in population from the agricultural sector continues, the rancher loses his political clout. A few years ago, nearly everyone was acquainted with agricultural problems—most people still had relatives on farms and ranches or were only "once



removed" from direct contact with the industry. This is no longer true. We have lost strength in numbers and lost public awareness of farming and ranching problems.

I'm proud to say that during this period—particularly during the last three decades—most ranchers have become "conservation" conscious, most have begun to work with the technically trained personnel of the Federal agencies as they saw the need for wise use of natural resources. Most ranchers can now identify the major plant species; most have good concepts of habitat requirements and carrying capacities; and most are conscious of wildlife relationships.

Suddenly, something else has happened! The average citizen has become "ecology conscious"—although many don't know the definition of the term. The environmental movement has swept through the country. Emotionalism about resource use and public land policies is at a new peak. And new heroes and new villains are emerging as the Thomas Principle (more or less) continues to operate. When the dust and dirt settle from the 1973 political storms, it will be difficult to tell the "white hats" from the "black hats."

Personally, I welcome the emergence of the science of ecology; *but*, I fear the emotionalistic approach of the amateur. I welcome the impact of all scientific disciplines on environmental problems; *but*, I am concerned about the elite scientist who gets out of his field and becomes an expert ecologist overnight. I am concerned about some interpretative news features and such biased approaches to conservation as was promulgated by the TV special called "Say Goodby." Aldo Leopold, a management ecologist if there ever was one, would turn over in his grave if he knew about some programs that were being promoted in his name.

Well, it should be obvious from my discussion of social and political considerations that unity is essential—unity among ranchers and other sectors of the livestock industry, unity among land management agencies and technicians, and unity between the livestock industry and technical and scientific personnel. Let's re-examine our own biases, let's unite to counter the pressures from extremists, let's fight to keep the "conservation rancher" of the year from becoming the culprit of tomorrow. The Society for Range Management can provide the means of bringing people together through rational discussion of research findings as they relate to political issues.

Ecological Considerations

As I stated earlier, I welcome the renewed interest in ecology and the environment. It is my hope that this interest will lead to a better understanding of the "scientific" principles of ecology and not just stir up the emotions. We need to make decisions based upon facts, not fears. In the long pull, public land use must be based upon sound ecological principles and practices.

I feel certain that there are "alternative" solutions to our pressing problems of environmental pollution and deterioration. The answer, in my opinion, is not to "stop everything"—to halt economic development, to stop progress on health care, consumer goods, and services.

Changes are necessary—changes must be made. But we cannot pass a retroactive birth control law; we cannot halt development by legislative edict. We must make provisions for the masses of people now on the planet Earth and somehow we must also plan for about 6.5 billion by the year 2000. We need to make provisions to house, feed, clothe, and care for these large numbers of people, and we must do so without further harm to the environment.

What have we learned from the science of ecology that could help us with environmental problems? More specifically, what have we learned from the many grazing experiments and biological studies that have been conducted over the last 30-40 years that could help us with decisions about grazing on public lands?

(1) First, we should have learned that *the world has changed, is changing,* and *will continue to change, regardless of man's efforts pro or con.* Even without man's influence the principles of geology are at work, weathering and geologic erosion are taking place, soil development is at work. The Genesis rock returned by the astronauts from the moon indicates that the world—our Planet Earth—has been in existence for over 4.5 billion years. Much change has occurred during these eons of time. The ecological principles of primary plant and animal succession, under the influence of climate, present evidence of change through time; and change in habitat means change in biological populations. One hundred-forty million years ago the dinosaur, the brontosaurus, and other prehistoric forage eating animals disappeared from the scene. Some of these species required 1 ton of forage per day and placed tremendous pressures on the vegetation resource. Factors were at work to bring about change even before the presence of mankind. Change in environment will continue, based upon natural forces which are always present.

(2) The second principle that we have learned from the science of ecology is that man has been and is influencing the environment on all areas of the earth's surface—and perhaps beyond. *Man is the great "accelerator of change."* Part of his efforts have been toward "intentional" management to improve crop and livestock production, to create better homes and more consumer goods, to make humid areas more arid, and to make arid regions productive and livable by irrigation and temperature control. By modifying his environment, man has added millions of acres to the production potential and created desirable living situations in hazardous climates for both rural and metropolitan living. In areas where the environment has been difficult to modify, he has adapted to the environment himself and modified the biological organisms using the area. He has developed drought-resistant plants, bred up animals to withstand climatic extremes, and learned to cooperate with the climate. He has introduced literally thousands of plants, brought in horses, cattle, and sheep and introduced many exotic species of wildlife. Thus, he has changed the vegetation complex and the animal populations. He has also brought about an industrial revolution to improve all forms of consumer goods. Many of these changes add up to man's credit, based upon goals established early in our history.

But, while man has thus been busy modifying the environment, adjusting the plant and animal life, and developing business and industry to serve his special needs, he has, for the most part unintentionally, created problems of pollution and contamination. He has had too little concern and too little understanding of the quality of the "total environment." He was not concerned about overgrazing and resource exploitation. He was not aware that his actions have influenced, either directly or indirectly, every area on the earth's surface.

(3) The third principle that we have learned from the science of ecology, combined with the lessons of history and economics, is that *all biological populations must ultimately be controlled by habitat limitations.* This principle applies to *Homo sapiens* as well as to the insect *"Begrothia steelia."* It applies to cattle,

sheep, goats, and deer.

When too much pressure is placed on the habitat, competition between and among species increases. The resource base is endangered or destroyed. Man, as a biological organism, coupled with his associated technological development, is presently being sustained by heavy drains on "depletable" resources—particularly fossil fuels. Our present ecosystems are not sustainable unless energy substitutes can be found. Man's technological development is also causing pollution and deterioration of "renewable" resources.

(4) Finally, *an understanding of the principles of ecology can only lead to the concept of "management" of the environment rather than "protection" per se.*

"Protection" could mean "hands-off," to "shield," or to "let nature take its course." Nature can be vicious; nature can be destructive. I much prefer the terms environmental *improvement* or *management.* These terms imply research, understanding, analysis, and planning. "Improvement" could lead to correction of the existing problems of environmental deterioration as well as "planned" growth and development with man as a part of the formula. We have no choice but to be concerned about *man's* need for consumer goods and well-being. *Ecological understanding and "management" orientation are essential.* I'm pleased to belong to the Societv for Range "Management" and not the Society for Range "Protection."

The vegetation complex as we know it today has evolved under millions of years of grazing pressure by various species of wildlife. We also know that by 1900 some U.S. ranges had already been subjected to 200 years of continuous close grazing—particularly in Texas, New Mexico, and Arizona (Dyksterhuis, 1972). We can make some fairly reliable observations from these historical treatments. More importantly, we can add to these qualitative interpretations literally thousands of man-hours of range research at experiment stations in each of the 17 western states.

I conclude from my examination of research in the last four decades that:

(1) On a limited number of sites, grazing by domestic livestock is detrimental to the resource and competitive with certain wildlife populations.
(2) On some sites, grazing by livestock can be the most beneficial use to society for economic, social, and ecological reasons.

(3) On vast areas of native lands, both public and private, grazing is compatible with other uses. There can be benefits to game animals, water yield, fire abatement, nutrient cycling, and people enjoyment from livestock grazing the public lands. Multiple use can be an ecologically sound objective on millions of acres of our public lands.

Ruben Pankey, of the New Mexico Cattle Growers Assn., stated recently (Pankey, 1973);

> We, in the livestock industry, who use public lands for forage purposes, are firmly committed to the multiple-use concept. This concept was not arrived at easily, but after several years of experience we find that we can live under this principle and even enjoy benefits from it, by demonstrating to the American public the values of the production of food and fiber. Forage, namely grass, is not a resource that can be harvested and stored. It has to be utilized in place, *properly*, by livestock and wildlife.

I italicize the term *properly* because this is the key to ecologically sound public land use. Poor management is always a bad practice. We know from our research that, while livestock numbers on Federal lands have been reduced over 50% since 1935, the number of big game animals has doubled (Clawson, 1967). Deer, which are competitive to a certain degree with all classes of livestock, have increased on many public and private range areas. Dr. Jim Teer (1972), after much research, states that the grazing regimes with cattle, sheep, goats, and deer on the Edwards Plateau of Texas are quite marvelous examples of efficient use of a complex vegetation. About 24 million pounds of meat are produced from the 300,000 deer harvested in Texas on ranges carrying deer and domestic livestock. In 1972, Jensen, et al. (1972) in Utah reported that sheep can use big game range without prohibitive use of bitterbrush and other shrubs, a possibility that previously had little support among many biologists." I could cite research indicating that grazing by livestock can be compatible with other uses in virtually every western state as well as in the southern and eastern forests.

As most of you know, there is a move afoot to eliminate all domestic livestock from public lands. Are we willing as a Society to abandon our long-term grazing research—to be carried along with the extremist who cries "protection" based upon fears (or in some cases evidence of poor management)? Shall we join the "purist" who omits man from the formula, or stay with our identification as "applied ecologists"?

This is a time for unity—unity among scientists, unity among range technicians, unity between these groups and conservation-minded leaders of the ranching industry; unity for economic reasons to help hold together a semblance of the free-enterprise system; unity for political and social reasons to strengthen the voice of rural America in an urban oriented world; unity for ecological reasons because of our concern for the environment.

Let us join together, at this time when the international interest in the environment is so high, to promote *more good, sound, long-range ecological research on alternative solutions to resource problems, better education on conservation practices, and stronger technical assistance programs to encourage range improvement.*

The Society for Range Management can be the most effective international organization to accomplish these objectives. But, don't forget the risk. I cite again the Thomas Principle (more or less):

> "Traditional heroes can become overnight villains with a change in the attitudes of people or the laws of the land."

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'Horizontal' Wells

W. T. WELCHERT AND BARRY N. FREEMAN

Highlight: *Forty-five horizontal wells were constructed on the San Carlos Apache Indian Reservation during 1967-69. This paper describes site selection, drilling equipment, and the construction process and lists the advantages of the horizontal well system over more conventional systems.*

Adequate water supplies, located for best utilization of range resources, are essential to good range management. A rancher doesn't need a large water yield in most areas. A single watering site can serve one to three sections of rangeland. In Arizona, the typical beef cattle stocking rate varies from four to ten animal units per section. At 12 to 15 gallons per animal-day, the maximum potential use per watering site is less than 500 gallons per day (gpd).

A yield of 0.25 gallons per minute (gpm) may serve a single watering site. A lesser flow may be utilized with the addition of tank storage designed to accumulate water to match the anticipated demand for the grazing season. Even spring sites that flow for only a few weeks in the year may prove useful with adequate storage.

A yield of 3 to 10 gallons per minute (4,000 to 14,000 gpd) may be extended to a dozen or more water sites through pipe distribution systems. One-inch pipe distribution systems of 10 miles or more are in use on a number of Arizona ranches.

Providing stock water at a suitable location and reasonable cost has always been a problem for the stockman. "Dirt tanks" (stock ponds) are relatively inexpensive, but reliability depends upon soil factors and rainfall. Runoff aprons and catchment basins are expensive, require some maintenance, and are dependent upon regular precipitation. Conventional wells are reliable but expensive, and associated pumping equipment may require considerable maintenance.

Properly developed springs approach the ideal range water supply specifications, but are often wasteful of water. Spring development is an ancient art. When a water seep or other evidence of a potential spring is located, it is either dug or blasted to expose the aquifer. The results are erratic and include the risk of permanently destroying a natural barrier which may be serving as a dam for the underground reservoir. The flow, once established, is almost impossible to control and may result in rapid depletion of the stored water. The horizontal well virtually eliminates the disadvantages of conventional spring development techniques. Each of these methods has a place in providing range water supplies and will continue to play a role.

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Fig. 1. *A completed horizontal well on the San Carlos Apache Reservation test yields over 50 gpm.*

Origin and Development of Horizontal Wells

Horizontal wells are a recent addition to the range water development picture. They have a tremendous potential in areas having favorable geological formations. Fortunately, such areas include a substantial portion of the better rangeland in Arizona and the mountain states.

A horizontal well is simply a horizontally-cased well in a water-bearing formation (Fig. 1). A "horizontal" boring rig (Fig. 2) is used to drill a hole and install pipe into a mountain or hillside at a slight downward slope to tap impounded groundwater.

Although miners, road builders, plumbers, electrical contractors, and geologists have developed equipment and techniques for horizontal boring, little attention has been given to adapting these techniques to water supply development. The equipment used to construct horizontal wells is also used to construct horizontal drains for control of landslides in

Fig. 2. *Horizontal well drilling equipment should be as light and portable as practical for use in rough range country. Note that water is recirculated through a rotary wet-boring drill stem. The heart of the rig is a pipe chuck which turns at about 100 rpm and is powered by a 10 hp gas engine.*

California. Hellesoe (1941) reported that the first installation of horizontal drains was made on the Cuesta Grade in 1939. In 1948, Stanton (1948) reported on the Hydrauger Method of installing horizontal drains on 53 landslide areas of the California highway system. Tripp (1963) credited Eric A. Anderson of Petaluma, Calif., with successful horizontal well drilling in the early 1950's. Root (1955) reported on the progress of horizontal drill equipment development. These reports indicate that equipment development was stimulated by drillers competing for highway drainage contracts and that the practice of horizontal well drilling evolved as a natural extension of earlier experience in constructing horizontal drains. It is also probable that a number of early innovators from both arts have contributed to the evolution of the equipment and drilling techniques. To date, the most effective equipment has been designed, built, and rebuilt by the drilling contractors.

The driller-cooperator on the San Carlos Apache Reservation has demonstrated three different "generations" of equipment while developing about 50 producing wells during the period from 1967 to 1969.

Site Selection

Potential sites are located by evidence of a water seep, presence of water-loving plants, or observation and analysis of geologic formations. Generally, a site will show geological evidence of either a natural dike or a "contact" type of spring.

The dike formation (Fig. 3) is a geologically tilted impervious formation, such as rock, which forms a natural barrier to an aquifer; in essence, a natural dam for an underground water storage reservoir. Water may not be visible, or it may seep through cracks in the dike or over the top of the barrier. The objective in horizontal well development of a dike formation is to drill through the barrier somewhere below the seep and tap the storage water.

The contact type (Fig. 4), consisting of a perched water table above an impervious material, is more difficult to recognize. Water seeps out at a point near the outcropping impervious layer. The line of seepage can frequently be located by observing the presence of water-loving plants. Drilling below the seepage will often fail to increase the yield because the entry may be into the impervious layer.

Drilling Equipment and Process

A rotary method of drilling is used with recirculating water to remove the drill cuttings. Standard lengths of 1¼-inch nominal diameter extra strength steel pipe are used as the drill stem. The drill bit is a standard pipe coupling with tungsten-carbide blanks welded into notches in the leading edge (Fig. 5) which bores a hole with a diameter about ¼-inch larger than the coupling. The drill bit must be small enough to clear the inside of a standard two-inch casing. The drill stem is clamped in a chuck and rotated at about 100 rpm as the chuck and stem are moved forward on a carriage. The equipment must be rugged and, equally important, light and portable for transport to sites in rugged terrain.

Drilling is started at a likely site with a minimum downward slope of ½-inch per foot. Water, pumped through the rotating drill stem, washes the cuttings back through the annular clearance between the hole and the stem. A portable gasoline engine-driven pump with at least 3 gallons per minute capacity at 120 pounds per square inch provides water return velocity of 1.0 to 1.5 feet per second necessary to cool the bit and to remove the cuttings. A continuous flow of return water is essential to prevent binding of the drill stem in the hole. Return flow is directed to a holding pond for settling and reuse. A readily available source of 100 to 300 gallons of water per day is necessary.

The drilling rate usually varies from 3 to 9 inches per minute through heavy clay, decomposed granite, or soft rock. In extremely hard rock, the rate may be less than 1 inch per minute. When this occurs, the carbide bit is replaced with a commercial diamond drill bit.

When the drilling produces evidence of a water supply, the exposed lengths of drill stem are removed, leaving just enough stem to serve as a guide for a two-inch casing. This stem is then equipped with a drill stem plug and pickup guide (Fig. 6) which serves to keep recirculating water out of the drill stem during placement of the casing. The tapered end of the plug also serves as a guide for recoupling to the drill stem for removal after the casing is set.

Cementing in the Casing

The two-inch casing, equipped with a carbide-tipped coupling, is used to ream the hole around the drill stem guide until contact is made with the impervious layer. Drilling is stopped when the exposed end of the casing provides a convenient location for an outlet tee connection. A section of pipe and a standard coupling is attached to the pickup guide, and the 1¼-inch drill stem is removed from the casing.

Another hole is then drilled immediately alongside the casing, penetrating several feet to form a control path for

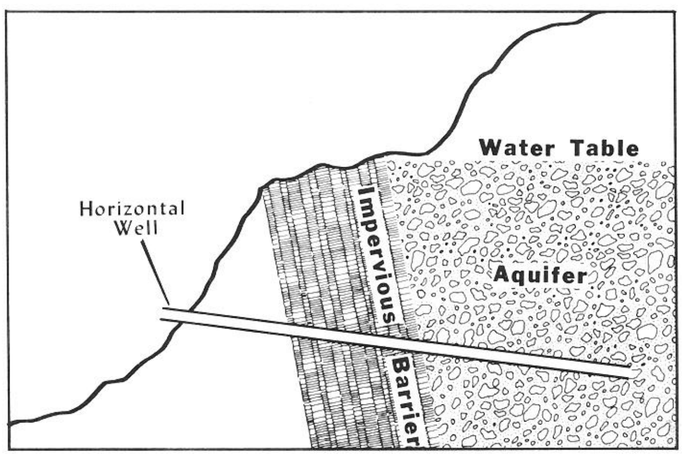

Fig. 3. *Dike spring formation.*

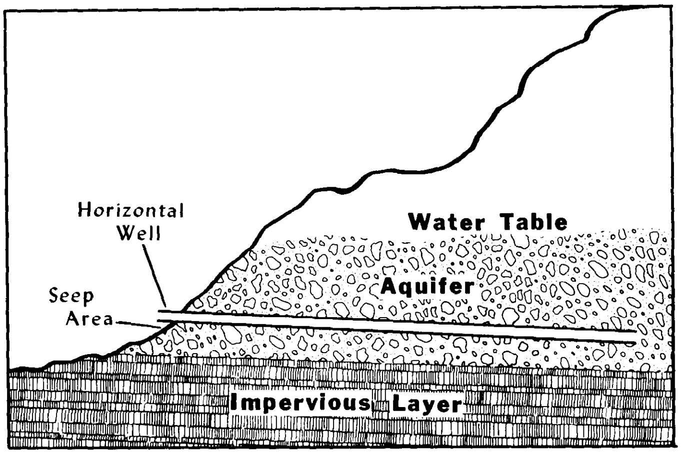

Fig. 4. *Contact type of spring formation.*

cementing the casing in place. A cement slurry pressure tank, containing about two sacks of plastic cement slurry mixed to a consistency of heavy cream is then connected, so that water pressure from the pump forces the slurry into the annular void and soil surrounding the casing. The drill stem is sealed at the ground by packing paper around the stem. Pumping is stopped when the cement begins to show in the casing return flow. The drill stem is then removed and the slurry is allowed to set, usually overnight.

The next morning, the drill stem is reinserted inside the casing and drilling continued until a satisfactory yield is established or until the practical limit of the drilling has been reached. The drill stem is then replaced with 1¼-inch perforated pipe, usually the full length of the hole or at least through the principal water-bearing strata, to keep the hole open.

Plumbing

The plumbing for the system is simple, consisting of a gate valve, vacuum relief valve, and fittings, all attached to a tee at the end of the casing. Normally, a bibb faucet is added to provide drinking water for both the ranchers and hunters. If the relief valve is subject to fouling from dirt or debris, a riser is included. With the well at a downward slope into the aquifer, the tee and air relief valve are at the high point in the system and the vacuum relief valve prevents the formation of a vacuum in the casing when flow rate exceeds water yield from the formation. If the vacuum were permitted to exist, fine grained materials would be sucked from the water bearing strata into the system.

The elevation of the water in the aquifer above the outlet provides a head of water, making this a completely automatic water system. From the tee, the necessary distribution pipe is connected to the float controlled watering sites.

Drilling Results

A serviceable water supply was obtained at 45 of the 53 locations where development was attempted on the San Carlos Apache Indian Reservation. It should be pointed out that success is a measure of both the driller's skill in site selection and the geological character of the area. Success was defined as a yield of 0.25 or more gallons per minute. Flow measurements were made after the plumbing of the well was completed, at which time the well normally had been running for a day or more. Yield estimates varied from 0.25 to 60 gallons per minute, and most were in the 3 to 10 gpm range.

Because every area has unique problems, drilling success and cost of development will vary considerably. Drilling distance at San Carlos varied from 41 to 270 feet and averaged 123 feet per producing well. Neither the shortest hole at 41 feet nor the longest at 270 feet were the least or most expensive site. The well record at the Blue Spring site shows a total development time of only 12 hours for a 101-foot hole, while at Johnny Spring, 52.5 hours were required to complete a 90-foot well. Development time averaged 32.3 hours per producing well.

The well construction costs averaged $500 per producing well, including $50 for plumbing supplies. This cost includes the dry holes and time spent on site preparation and road building, but does not include pipe distribution and water tank systems.

Advantages

The horizontal well system has a number of advantages over other range water supply systems:

1) When compared with conventional springs, water loss is minimized since the flow can be controlled by float valve or completely shut off when not required.

2) The system provides a sanitary water supply. Normally, spring water supplies are of good quality and purity as they emerge from the ground. However, contamination in a spring area is common and difficult to control. With the horizontal well, the possibility of contamination at this point is virtually eliminated.

3) The cost of the horizontal well will normally be substantially less than other water supply systems. The construction cost is moderate; maintenance cost is low and the operational cost is insignificant.

4) The chances of developing a successful water supply with a horizontal well are greatly improved over conventional spring development methods. Several of the better yielding wells in the San Carlos area were developed where there was no evidence of a spring or water seep.

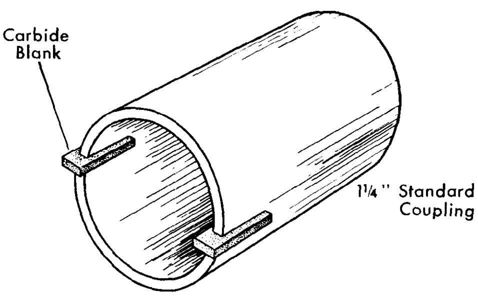

Fig. 5. *Drill bit.*

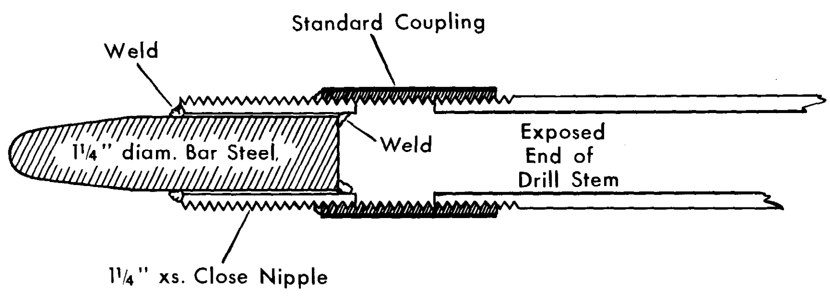

Fig. 6. *Drill stem plug and pickup guide.*

Arizona ranchers are enthusiastic about the potential application of horizontal well drilling in remote and rough country.

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Evaluation of Eastern Redcedar Infestations in the Northern Kansas Flint Hills

CLENTON E. OWENSBY, KENNETH R. BLAN, B. J. EATON, AND O. G. RUSS

Highlight: *Associations among cattle stocking rate, precipitation, and eastern redcedar invasion, and possibly redcedar control measures were investigated. Redcedar numbers generally decreased as stocking rate increased. Precipitation had only a slight effect on invasion rate. Fire, cutting, and fenuron granules appear to effectively kill redcedar.*

The recent rapid invasion of eastern redcedar (*Juniperus virginiana* L.) into tallgrass prairie concerns ranchers and professional range managers.

Redcedars have become prominent since 1960 in areas not occupied previously. Some pastures severely invaded by eastern redcedar join pastures where they are completely absent. Factors involved in rapid invasion by eastern redcedar are not known.

Opinions held by local landowners include a reported large increase in starling (*Sturnus vulgaris britannicus* Bullough) populations in the early 1960's. Redcedar seeds are spread by various species of birds. Parker (1951) reported starlings as one such species. Some small mammals damage young redcedar seedlings. The decline of some rodent species may have decreased destruction of redcedar seedlings. Government programs promoting eastern redcedar for windbreaks, erosion control, and wildlife cover have increased the seed supply. Both hypotheses may be partially valid, but they cannot be substantiated statistically.

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Eastern redcedar is not capable of suckering or resprouting if cut below the bud zone. When the top is cut off below the lowest limb, or is killed by fire, the tree roots usually die from lack of top growth to support them. Fire severely reduces redcedar populations. (Arend, 1950; Dalrymple, 1969).

We investigated the associations among cattle stocking rate, precipitation, and eastern redcedar invasion, and possible control measures.

Study Areas and Methods

The study area was in the True Prairie of northeast Kansas Flint Hills near Manhattan, Kans. Vegetation was predominantly big and little bluestem (*Andropogon gerardi* Vitman and *A. scoparius* Michx.), Indiangrass (*Sorghastrum nutans* (L.) Nash), switchgrass (*Panicum virgatum* L.), and numerous other less important grasses, forbs, and woody species.

Average annual precipitation at Manhattan was 32 inches during 1959-1969, 69% during April through September. Average frost-free period is from April 20 to October 10. The elevation of the study pastures is approximately 1,100 ft above mean sea level.

Range Sites

Soils of the study areas were grouped into range sites to eliminate soil differences. Soil series within a range site have essentially the same plant community and production potential when in climax condition.

Loamy upland range site consists of soils having medium-textured soil deep enough to support primarily big bluestem and Indiangrass in climax condition. Predominant slopes are 1 to 5%.

Limestone breaks consist of soils on predominantly 15 to 30% slopes. Loss of moisture by runoff is greater than on loamy upland, but the soil is deep enough to support vegetation similar to that found on loamy upland. Limestone rocks usually occur throughout the profile and on the surface.

Clay upland consists of soils on 0 to 3% slopes mostly on ridges. The soil is finer-textured and more droughty than loamy upland. Vegetation varies widely but includes big and little bluestem with a higher percentage of secondary grasses than on loamy upland.

Limy upland, though similar to loamy upland, has limestone concretions in the profile and on the surface. The soil is deep enough and has water relations that favor vegetation similar to that on loamy upland. Predominant slopes are 3 to 8%.

True Prairie range sites are described in detail by Anderson and Fly (1955).

Main Study Areas

Eight pastures were selected as main study areas in Riley and Pottawatomie counties to evaluate stocking rates and precipitation effects. Criteria for pasture selection included availability of management records, willingness of landowner to cooperate, and range sites to be studied. Main study areas were all grazed pastures with known management histories for 1960-1968. They ranged from 63 to 237 acres and totaled 1,062 acres. Four study areas had light to moderate invasions of redcedar (5 to 20 trees/acre), and four had heavy invasions of eastern redcedar

(30+ trees/acre).

One hundred circular, tenth-acre plots (37.25 ft diameter) were randomly located in the heavily-invaded pastures; 100 were located in the lightly to moderately-invaded ones. Number of plots in each pasture was in proportion to the pasture size, approximately 1 plot/5 acres.

Information collected on each plot in the main study area included: number of trees, number of trees producing seeds in 1969, tree age, range site, estimated range-condition class, direction of slope exposure, other brush species present, and estimated abundance of other brush. Cattle stocking rates for each main study pasture from 1960 through 1969 were recorded.

An additional 100 trees (25 from each range site) were cut to obtain height, diameter, and age of trees in the study areas. Tree height was measured to the nearest inch; diameter was measured to the nearest 1/100 inch at soil level.

Supplemental Pastures

Thirty supplemental pastures were observed to give the study a broader base. Ten pastures in each of the following categories were selected: essentially no redcedar invasion, light-to-moderate invasion, and heavy invasion of redcedar. Information secured from tenants or landowners for the supplemental pastures included grazing history for 1960-1968, burning history, and a visual estimate of redcedar invasion.

Control Methods

Foliar-applied herbicides, soil-applied granular herbicides, and controlled burning were tested as control measures. Herbicide treatments were applied to 10 individual trees, each tree a replication in a completely random design.

Foliar-applied herbicides were applied April 9, 1969, with a hand boom attached to a tractor mounted compressed-air sprayer and trees were sprayed until the solution ran off the leaves. Redcedar trees were approximately 1 to 6 inches trunk diameter and 2 to 12 ft tall.

Granular herbicides were applied April 10, 1969, to the soil surface within a 2-ft radius of the base of each tree. Rates were determined by tablespoons of granules per inch of tree trunk diameter at ground level. Trees were approximately 4 to 12 inches in diameter and 10 to 30 ft tall.

Herbicide treatments were evaluated, and percentage of control was estimated four times during 23 months after application. Control was assessed by dead leaves, branches, and above-ground plant parts affected by treatments. Dead trees were counted 12 to 23 months after treatment to ascertain actual plant kill.

Table 1. Average number of redcedar trees per acre and years established.

Tree density	Year established[1]									
	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Heavy	7.8	2.0	13.2	18.0	53.5	32.2	19.0	19.8	4.2	4.2
Light	0.5	0.2	0.8	0.5	3.0	3.0	0.2	3.2	2.2	2.0

[1]Overall L.S.D. .05 = 13.7.

One pasture was burned April 24, 1971. Range condition was excellent, and the area had an abundance of mulch. The fire traveled with a wind of approximately 3 to 5 mph. Individual redcedars were selected throughout the pasture before the fire and were tagged and divided into three size classes for post-fire evaluation. Tree height classes were defined as: seedling trees less than 2 ft, small trees 2 to 6 ft, and medium trees more than 6 ft. Control and apparent kill were assessed by methods identical to those used for herbicide treatments.

Results and Discussion

Approximately 48% of the redcedars on the main study areas germinated in 1963 and 1964, and 96% were less than ten years old. Significant differences in the number of redcedars established among years existed only in the heavily-invaded pastures (Table 1).

Differences among years on the heavily invaded pastures showed a sigmoid population increase curve (Fig. 1). On lightly invaded areas no similar increase occurred.

Effect of Grazing Management

Management factors other than burning or mechanical removal, which were significantly related to redcedar invasion, included growing-season cattle stocking rates for the year of germination plus grazing the preceding year. Effects of grazing as long as 3 years before the year seed germinated seemed to affect invasion rates. Grazing level apparently influenced the amount of mulch, and indirectly regulated redcedar establishment.

Growing-Season Stocking Rate

Redcedar invasion rate generally declined as growing-season (May-October) cattle stocking rate increased. That relationship was true on all range sites and pastures as well as for loamy upland and limestone break sites individually. The clay upland and limy upland range sites showed no statistically significant trends with growing-season stocking rate and redcedar invasion. The 1963 redcedar invasion rate declined 6.3 trees per acre per animal-unit-month (AUM) of additional grazing. In 1964 the decline was 13.8 trees per acre per additional AUM of additional grazing (Fig. 2). Redcedar invasion rates were highest during those two years. Heavier stocking rates during the growing season resulted in fewer redcedars.

Redcedar establishment in 1968 did not follow the trend described by Meines (1965) where successful establishment from seed required cool, moist soil. In 1968 heavy grazing during the growing season increased redcedar invasion. Apparently there was a critical amount of soil mulch required for redcedar establishment. Too much or too little mulch seemed to retard redcedar invasion.

Nongrowing-Season Stocking Rate

Nongrowing-season stocking rate affected redcedar invasion on some sites in some years. In all cases where a significant trend ($P < 0.10$) was found, an increase in nongrowing-season stocking rate decreased redcedar invasion rate. A slight decrease in redcedar number with increased nongrowing-season stocking rate occurred in 1964 on the lightly invaded pastures and in 1966 on the limestone breaks site in all pastures. Over all sites and pastures in 1967, increases in nongrowing-season stocking rate decreased trees 2.3 per acre for each additional AUM of grazing (Fig. 3). The decreased redcedar invasion rates may have resulted from the decreased mulch left on the soil following winter grazing.

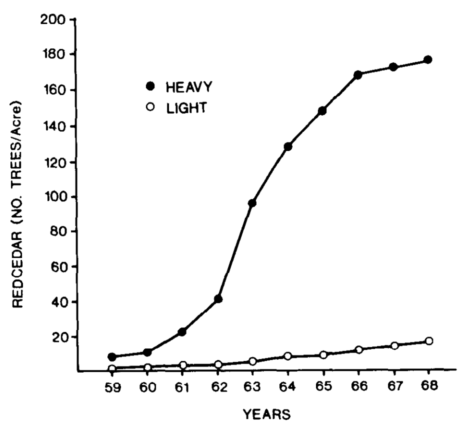

Fig. 1. *Cumulative number of redcedar trees per acre on heavily and lightly infested areas from 1959 through 1968.*

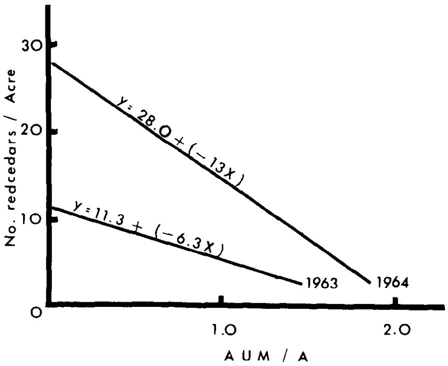

Fig. 2. *Relationship between growing-season, cattle-stocking rate, and redcedar numbers over all sites and pastures for 2 years of greatest redcedar invasion.*

Less mulch would be expected to result in less redcedar germination and/or survival (Meines, 1965).

Precipitation Effects

Total precipitation during the year redcedar was established had a statistically significant effect on redcedar invasion. On the heavily invaded areas, for each additional inch of precipitation, invasion rate decreased only 0.2 tree per acre.

The relationship between precipitation and redcedar establishment may be coincidental. The large increase in redcedar in 1963 coincided with an extremely low rainfall year, approximately half of normal. That increase occurred during the accelerated population increase of an apparent sigmoid population increase curve (Fig. 1). Precipitation in 1964 and 1965 was above average, and redcedar establishment was high both years.

Apparently, redcedar can withstand severe drought in eastern Kansas. In 1939, Albertson (1940) reported that up to 80% of eastern redcedar died near Hays, Kans., in the drought of the 1930's. The three areas he studied were near the western edge of the range of redcedar. Pool (1939) found redcedar in eastern Nebraska had suffered no great damage during the same drought.

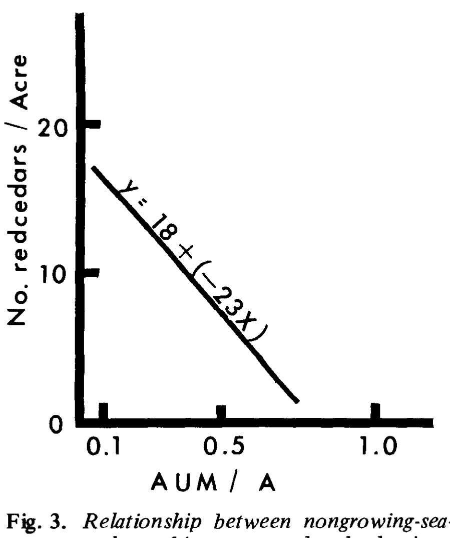

Fig. 3. *Relationship between nongrowing-season, cattle-stocking rate, and redcedar invasion for 1967.*

Table 2. Frequency (%) of other woody species in the main study plots.[1]

Redcedar density	Osage orange	Buck-brush	Roughleaf dogwood	Elm	Honey locust	Wild plum	Aromatic sumac	Smooth sumac
Heavy	4.5	25.8	25.0	1.0	4.5	3.2	14.2	52.8
Light	0.0	51.2	3.2	12.2	0.0	0.8	2.8	9.8

[1]Overall L.S.D. .05 = 12.4.

Frequency of Occurrence of Associated Brush and Tree Species

Apparently the same factors that retard redcedar invasion generally retard invasion by osage orange (*Maclura pomifera* Raf.), roughleaf dogwood (*Cornus drummondii* Meyer), honeylocust (*Gleditsia triacanthos* L.), and smooth sumac (*Rhus glabra* L.). Buckbrush (*Symphoricarpos orbiculatus* Moench), and elm (*Ulmus* L. sp.) were more abundant in pastures lightly invaded by redcedar than in heavily invaded pastures (Table 2); however, buckbrush and elm populations were lower on pastures with no redcedar than on pastures moderately or heavily invaded by redcedar.

Age, Diameter, and Height of Redcedars Correlations

Year of germination compared with average diameter at ground level and height (including 1970 growth until May 7, 1970) are given in Table 3. Linear regression indicated diameter increased 0.27 inch, and height increased 7.85 inches for each year of age. Range site did not differentially affect redcedar height and diameter in relation to age.

Slope Exposure

No significant differences existed among redcedar populations on various slope exposures.

Fire and Cutting

Fire and cutting were the only factors consistently associated with absence of redcedar invasion in the 30 supplemental pastures. History of those pastures shows no apparent relationship between stocking rate and redcedar invasion. All pastures free of redcedars had been burned or had redcedars mechanically removed.

Range Sites

No significant differences in redcedar numbers were found among the loamy upland, limestone breaks, clay upland, and limy upland range sites.

Seed Production

Trees 6 to 7 years old produced seeds. Secondary invasions from existing trees could occur 6 to 7 years after tree establishment.

No detailed information was gathered on proximity of a seed source and its effect on invasion rate.

Foliar Applied Herbicides

Foliar-applied herbicides partially controlled redcedars but did not kill any (Table 4). Highest rates of picloram and picloram plus 2,4,5-T or 2,4-D were more phytotoxic than other treatments at 4- and 8-month interval evaluations. Results

Table 3. Age (years), diameter (inch), and height (inch) of redcedars from loamy upland, limy upland, clay upland, and limestone breaks range sites.

Year of germination	Age	Average diameter at ground level	Average height	Range of diameters	Range of heights	No. in this age class sample
1969		0.04	2.0	0	0	3
1968	1	0.12	8	–	–	1
1967	2	0.28	12.5	0.20–0.23	11–15	4
1966	3	0.47	20.2	0.31–0.67	12–24	9
1965	4	0.71	26.1	0.51–1.18	16–42	7
1964	5	0.84	30.3	0.63–1.26	21–47	8
1963	6	1.12	43.4	0.83–1.89	24–64	28
1962	7	1.60	58.2	1.06–2.28	29–75	15
1961	8	1.62	57.4	0.47–2.48	30–76	14
1960	9	2.32	73.3	0.94–3.07	24–90	7
1959	10	3.27	84.5	3.15–3.39	79–90	2
1958	11	2.13	70.0	–	–	1
1957	12	3.03	80.0	3.0	80–83	2

Table 4. Control (%) and actual kill of eastern redcedars after application of herbicides (lb aihg) in foliage-wetting sprays.

Treatment - Rate[1]	Percent control				Number of dead trees	
	4 mo	8 mo	12 mo	23 mo	12 mo	23 mo
Picloram 0.5	6 c[2]	15 de	9 cd	24 ab	0	0
Picloram 1.0	33 b	55 a	40 a	39 a	0	0
Picloram + 2,4,5-T (0.5 + 0.5)	12 c	23 bc	9 cd	21 abc	0	0
Picloram + 2,4,5-T (1 + 1)	47 a	38 abc	25 abc	21 abc	0	0
Picloram + 2,4-D (0.5 + 1)	5 c	19 cd	9 cd	15 bc	0	0
Picloram + 2,4-D (1 + 2)	43 ab	41 ab	27 ab	38 a	0	0
Picloram + Amitrole + NH_4 CHN (0.5 + 1 + 0.9)	10 c	17 cde	9 cd	19 abc	0	0
Picloram + Banvel (0.5 + 1)	7 c	34 abcd	15 bcd	38 a	0	0
Control	0 c	1 e	0 d	1 c	0	0

[1] Pounds active ingredient per 100 gal water carrier.
[2] Numbers in a column followed by a common letter do not differ significantly ($P < 0.05$).

Table 5. Control (%) and actual kill of eastern redcedar after application (tbs/inch basal diameter) of granular herbicides.

Treatment	% ai[1]	Rate	% control				No. of dead trees	
			4 mo	8 mo	12 mo	23 mo	12 mo	23 mo
Fenuron	25	0.25	17 e[2]	23 d	14 cd	14 e	0 c	0 c
Fenuron	25	0.5	42 d	29 d	17 c	36 d	0 c	0 c
Fenuron	25	1.0	80 b	75 b	84 a	90 ab	1 c	3 b
Fenuron	25	2.0	99 a	99 a	100 a	100 a	10 a	10 a
Picloram	2	1.0	46 d	46 c	59 b	70 c	0 c	1 bc
Picloram	2	2.0	65 c	69 b	59 b	80 bc	0 c	2 bc
Karbutilate	10	1.0	62 c	74 b	85 a	96 a	4 b	8 a
Karbutilate	10	2.0	71 bc	75 b	99 a	100 a	9 a	10 a
Control		0	0 f	0 e	0 d	0 f	0 c	0 c

[1] Percent active ingredients in commercial formulations.
[2] Numbers followed by a common letter do not differ significantly.

Table 6. Control (%) and number of dead trees per acre of eastern redcedar 4 mo after burn.

Tree size[1]	Sample size	Percent control	Number of dead trees
Seedlings	25	89	18
Small	25	83	12
Medium	10	39	2

[1] Seedlings, less than 2 ft tall; small, 2–6 ft tall; medium, taller than 6 ft.

from foliar-applied herbicides 23 months after treatment did not differ significantly, but all differed from the control.

Watson and Wiltse (1964), Dalrymple (1969), and Buehring et al. (1971) found foliar-applied picloram satisfactorily controlled redcedar. Their picloram in combination with 2,4-D, 2,4,5-T, dicamba, and amitrol plus NH_4CN at rates comparable to rates we used gave similar results. The data suggest that redcedar either does not absorb foliar-applied herbicides well enough to kill the plant or that quantities absorbed are not translocated to the roots. Cuticle wax could be a barrier to absorption.

Herbicide granules (Table 5) controlled redcedar more effectively than foliar sprays. Fenuron, picloram, and karbutilate granules at 1–2 tbs/inch basal diameter gave 70 to 100% redcedar control 23 months after treatment. Fenuron at 1 to 2 tbs/inch basal diameter effectively controlled redcedar, while rates of 0.25 to 0.5 tbs/inch basal diameter did not. Fenuron applied at 2.0 tbs/inch basal diameter killed all redcedars, but 1.0 tbs/inch basal diameter killed only 30% of them.

Picloram granules gave slightly less redcedar control than the highest rates of fenuron and karbutilate; however picloram granules were only 2% a.i. compared with 25% a.i. and 10% a.i. for fenuron and karbutilate. Picloram granules controlled redcedar much more effectively than foliar sprays. Karbutilate granules effectively controlled redcedars at 1 and 2 tbs/inch basal diameter. Both rates gave high control by killing plants, as shown 23 months after application.

Control by Fire

Small redcedars were affected more by fire than larger trees (Table 6). Fire controlled 89% of seedlings. Fewer trees more than 6 feet tall were killed by fire than seedlings or trees less than six feet tall. Fire controlled 83% of small trees. Fire controlled 39% of medium trees.

Main study pasture 1 in the precipitation-and-stocking-rate study was burned in April 1969. Dead redcedars that could still be identified were included in the count. Many smaller seedlings probably were consumed and, therefore, were not included. That was the only main study pasture burned between 1960 and 1970. Redcedars killed by that fire were counted. Approximately 63% of all age classes were dead.

These and other data (Dalrymple, 1969) suggest that small redcedars can be effectively eliminated by fire, but to control larger trees an alternative measure such as a herbicide treatment or mechanical removal is usually required. Some fires kill redcedar trees up to 20 feet high. Research on proper timing and amount of combustible material is needed.

Conclusions

1. Redcedar were most restricted by fire or cutting.
2. Heavier stocking rates seemed to reduce redcedars in the bluestem growing season as well as in the dormant period.
3. Redcedars appeared to invade all upland range sites equally.
4. Slope exposure did not significantly alter redcedar populations.
5. Invasion of redcedars was accompanied by other brushy species.
6. Redcedars 6 to 7 years old produced seeds.
7. Redcedars in the study area grew approximately 0.27 inch in diameter and 7.85 inches in height yearly.
8. Herbicide granules controlled redcedar more effectively than foliar sprays.

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Aspen Regrowth in Pastures of the Peace River Region

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Highlight: *Low-cost methods are required for converting wooded areas of Canada's Peace River region to productive pasture. Methods of circumventing the costly procedures of breaking the soil and removing roots preparatory to seeding were investigated. Various tillage implements (mouldboard plow, Rome disc–at 3 depths, rotovator, one-way disc, and tandem disc) were compared as to effectiveness for seedbed preparation. In addition, seed was both drilled and broadcast. Forage yields varied greatly, from an average of 1,184 lb/acre on the plowed plots to 103 lb on the check area. It was concluded that all methods tried tend to enhance tree establishment. Because of this, none of the methods tested would bring about an economically viable pasture.*

It has long been advocated that livestock must be an integral part of the agriculture of the northern parts of British Columbia and Alberta. The grey wooded soils of the area dictate that development will be based on mixed farming rather than on a monoculture of cereal production in order to balance the poor crop years. British Columbia has 1.5 million acres reserved, of which 6,500 have been improved. Alberta has 60,000 acres with 17,500 improved. These tracts of land are strategically located with respect to farming areas and are being developed for livestock pastures. For the most part, the areas are heavily forested with aspen (*Populus tremuloides* Michx.). These trees vary in density from 250 to 2,000 stems per acre and from 2 to 8 inches dbh (diameter-breast-high). They have to be cleared from the land, using various mechanical methods (Friesen et al., 1965). The land is broken by using heavy machinery and then seeded.

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The Problem

The main problem with pasture establishment after land clearing is the regrowth from suckers and roots of trees and brush. Any method of pasture preparation that allows the forest to easily regain its hold on the land is less than satisfactory. The methods used and the timing of clearing would appear to favor the regeneration of aspen. In addition to aspen, various species of willows (*Salix* spp.) as well as many other natives, such as rose (*Rosa* sp.), having the capability of vegetative propagation, attempt to repopulate the land.

Establishing a competitive crop of forage to help eliminate the brushy species has met with varying degrees of success. The problem, therefore, was to find the most satisfactory method assuring a reasonably good pasture for a minimum of time and expense that could be applied to large areas.

Procedure

An equipment trial was established on an area of 8 to 10-inch dbh aspen, which would be classed as type 4 cover (Friesen et al., 1965). The trees were "walked down" by crawler tractor and piled in March, 1963. The soil was a sandy loam (Beryl series). The trial consisted of plots 50 x 48 ft laid out in three replicates with 30-ft alleys used for turning areas. The machinery was pulled with a small crawler tractor. A 22-inch breaking plow was used, compared to three different depths of a 24-inch Rome disc, (D-deep, M-medium, S-shallow), a Howard rotovator, a one-way disc, and a tandem disc; a seeded check plot was established. Plots were split after cultivation on June 25, 1963, and seed was drilled on one half using a double disc drill; on the other half

Table 1. Number of plants on 60 ft² from drilled (D) and broadcast (B) seedings using various tillage methods.

	Aspen				Willow				Rose				Legumes			
	1964		1969		1964		1969		1964		1969		1964		1969	
Tillage methods	D	B	D	B	D	B	D	B	D	B	D	B	D	B	D	B
Mouldboard plow	11	0	2	0	2	1	1	1	18	26	15	7	4	92	3	4
Rome deep	2	4	1	2	6	6	2	0	26	16	11	7	28	92	4	8
Rome medium	8	10	4	4	8	0	2	4	42	34	14	11	30	58	1	5
Rome shallow	10	14	9	7	8	8	2	4	32	38	15	14	40	76	1	7
Rotovator	2	2	2	3	5	4	2	1	22	14	19	20	30	132	1	1
One-way	10	10	1	4	0	8	3	1	28	12	12	13	32	84	6	10
Tandem disc	30	48	19	16	16	12	6	4	72	50	12	9	24	36	1	3
Check	42	24	28	22	0	10	12	9	58	74	21	17	0	0	0	0

seed was broadcast using a Century seeder. The seeding mix was Rambler alfalfa, Manchar bromegrass, Olds creeping red fescue, and Aurora alsike clover at 3,5, 3, and 2 lb/acre, respectively. Seeds of legumes were appropriately inoculated. Plots were cut by hand to 2 inches, using a 9.6 ft² frame, 2 frames/sub-plot. Oven dry weight of forage was calculated each August for the years 1964, 1965, 1966, and 1969. Plant counts for legumes, poplar, willow, and rose were made in 1964 and 1969 by counting along a 20 x 1-ft line transect in each sub-plot. Cattle were allowed to graze the plots freely, along with the rest of the seeded pasture each fall during September.

Results

Establishment and Persistence of Seeded Species

Legume establishment, alfalfa and alsike clover, as shown in Table 1, was far greater for the broadcast plots than for those that were drilled. The greatest number were established in the rotovated plot. Perhaps this was because it was the smoothest seedbed. In all treatments the numbers of legume plants were reduced to very few per plot after 5 years. Alsike clover was nonexistent, and the surviving alfalfa plants were large and robust. The establishment of seeded grass was reflected in the yields as presented in Table 2. After 5 years the dominant grass was creeping red fescue.

Yields

A record of forage yields is shown in Table 2. Yield of dry matter was low during the year following seeding. In the second and third year the tandem disc plots and check gave significantly lower yields than the other treatments. By 1969, the check plot had filled in with 1 to 1½-inch diameter aspen, which impeded the growth of grazeable forage (Fig. 1). Drilling in the seed failed to promote higher herbage yields, compared to broadcast seeding. Wide fluctuation in yield from year to year reflects the precipitation for the growing season and represents a major difficulty in managing these man-made ranges.

Fig. 1. *Check plot showing aspen regrowth 6 years after tree removal and seeding to forages. The pathway in the foreground, which received considerable tillage before seeding, displays an excellent stand of alfalfa with no aspen regrowth.*

Woody Regrowth

A record of the major woody regrowth response is presented in Table 1. The mouldboard treatment produced the lowest number of stems of aspen and willow. In 4 years a 50% reduction of woody regrowth was recorded for this treatment. The shearing action of a mouldboard blade cut the roots below the growing points and threw the severed crowns to the surface; thus the regrowth of the larger species such as aspen and willow was reduced. Rose roots occur in the surface layers and reproduction is by rhizomes. Plowing merely turned the layer over without disrupting growth.

The Rome disc treatments produced more woody regrowth than the plow. The number of regrowth stems decreased with the depth of discing. After 5 years the amount of aspen and willow remaining on the shallow-and medium-disced plots was greater than can be tolerated on a pasture. The Rome disc chopped and sliced on a shallow setting, thus splitting crowns of willow and aspen, which allowed for numerous regrowth possibilities. On a deep setting it threw the soil, which brought more of the roots to the surface.

The rotovator churned the surface layer to a depth of 4 to 6 inches, chopping up the finer roots into short lengths and kicking the larger roots to the surface. Unfortunately, it jumped over heavy stumps and larger willow crowns which provided regrowth. Rose rhizomes were cut up and incorporated on the fluffed-up layer, providing a ready source for re-establishment.

The one-way disc produced results similar to the shallow Rome disc. It appeared to be too light for efficient surface cultivation. Here again the chopping action helped to re-establish the rose. The tandem-disc proved far too light, as it did not penetrate well and did not cut the tree crowns. It too increased

Table 2. Production (lb/acre, oven-dry) of forage for 4 years, Groundbirch, B.C.

Tillage and seeding methods	1964	1965	1966	1969	Avg
Tillage methods					
Mouldboard plow	529[1]	1.960 a[1]	936 a	1,093 a	1,129 a
Rome deep	581	1,850 a	883 a	1,419 a	1,184 a
Rome medium	459	1,210 a	717 a	1,088 a	868 a
Rome shallow	537	1,440 a	552 a	1,242 a	944 a
Rotovator	601	1,190 a	583 a	950 a	826 ab
One-way	556	1,793 a	710 a	1,462 a	1,130 a
Tandem disc	200	350 b	240 b	1,025 a	455 bc
Check	175	49 b	94 b	96 b	103 c
$\bar{x}$	455	1,230	589	1,041	829
$S\bar{x}$	±108	±298	±156	±212	±122
C. V.%	41	42	46	35	25
Sig.[2]	NS	.05	.05	.05	.05
Seeding methods					
Drilled	415	1,215	589	898	779
Broadcast	494	1,248	590	1,185	879
Sig.[2]	NS	NS	NS	NS	NS

[1] Means followed by the same letter within columns are not significantly different by Duncan's multiple range test at .05 level of probability.
[2] NS = differences not significant; .05 = differences significant at the 5% level.

the rose regeneration.

Check plots were seeded but received no cultural treatment. Here the aspen and willow came back unhindered. Some reduction in stems of aspen and rose occurred over the 5 years owing to plant competition. The seeded species did not establish. Any forage yield taken consisted of native plants only.

Discussion

Zehngraff (1947), discussing the possibilities of managing aspen in the Lake States, showed that root suckers are produced by dormant buds on the horizontal roots near the surface. He found that winter-logged areas give abundant regeneration and summer-logged give nonsatisfactory regeneration. He reasoned that aspen roots are depleted of their stored food during the active growing season and suckers establishing late in the season are winter killed. On one of his areas where regeneration was poor, cross discing increased suckers from 750 to 2,400/acre. On our check plots we had over 20,000 suckers/acre. Maini and Horton (1966) showed that temperature plays an important role in sucker initiation. Temperatures below 60°F or above 95°F inhibit sucker formation. They have shown that darkening the soil surface increases soil temperature. This insolation factor is cardinal for sucker stimulation. They speculated that diurnal temperature fluctuations play a favorable role in sucker initiation and tend to disagree with Farmer (1962) that aspen suckers appear on root systems only after the stems are cut, but not while trees are undamaged or vigorously growing. Kozlowski (1960) stated that the total amount of seasonal height growth in aspen is correlated with the size of the terminal and is better related to environment of the previous season than to the current season.

By looking at the factors involved in stimulating and maintaining aspen, it becomes obvious that "land-clearing" dormant trees in the Peace River region enhances rather than limits subsequent sucker production. There is, of course, good reason for recommending winter land-clearing in that it disturbs less top soil and the heavy crawlers can move more easily over the frozen surface. The machinery trials reported here do indicate that certain implements and procedures are superior to others. Degree of cultivation has a bearing on forage establishment, as observed from the excellent stands of grass and legume occurring in the highly developed seedbeds on the pathways caused by turning the equipment. If we consider that even 1,400 suckers/acre as produced by the mouldboard treatment is the first step in a succession back to an aspen forest, then none of the methods used is satisfactory. The production of large scale pastures, therefore, cannot be successful using rough or once-over methods. The conclusion differs from that of Bailey (1972), who obtained satisfactory stands using a tandem disc and grain drill on newly cleared aspen parkland on a dark grey wooded soil. He followed this in one year with a herbicide treatment to help eliminate the brushy species. His total yield 2 years after seeding was between 1,000 and 1,300 pounds per acre of dry grass-legume forage.

On the grey wooded soil of the Peace River region, pastures will have to be gradually created by the use of annual grain cropping for 1 or 2 years to assure adequate brush removal and the crop used to partially defray the additional expense. This could be done along with an adequate aerial spray program prior to establishing a permanent grass-legume stand.

The production of usable forage from the trials reported was disappointingly low with an average of 1,184 pounds/acre. These studies were conducted without supplemental fertilizers. Subsequent investigations (unpublished data) on these soils have shown substantial yield responses to N and S. In most years fertilizers can be profitably used to increase production.

Even without fertilizers production was 10 times that produced from the noncultivated check. Pastures as described have a limited life, and the cost of about $40/acre must be borne by increased production. This would mean that at least 6 years of production are necessary to break even. Should other costs of the pasture, such as fences, be included, then at least 10 years of good production would be required. Observation has shown that without additional spray programs or subsequent tillage the brush and trees will have dominated the stand in 10 years and production of forage for grazing will have been drastically reduced. It may then be concluded that there is no rapid, inexpensive cultural method to turn an aspen forest into a permanent productive pasture in the Peace River area.

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Value of Black Hills Forest Communities to Deer and Cattle

Fig. 1. *Understory cover of most species was greater in aspen communities shown here than in aspen-pine or pine. Fifty-four species of shrubs and forbs were found in the aspen communities. (U.S. Forest Service photo by Kieth E. Severson)*

JEREMIAH J. KRANZ AND RAYMOND L. LINDER

Highlight: *Aspen, pine, and mixed aspen-pine communities were studied at three different locations in the Black Hills National Forest of South Dakota from 1968 to 1970. Overstory densities were greatest in pine with a basal area (diameter at breast height) of 180.5 ft² per acre. Aspen-pine had 133.6 ft² per acre and aspen 89.5 ft² per acre. Understory production was inversely related to overstory density with 590 lb/acre air-dried forage in aspen, 415 lb/acre in mixed aspen-pine, and 215 lb/acre in pine. Aspen communities appeared to represent better feeding areas for both deer and cattle than mixed aspen-pine or pine. However, use by white-tailed deer, estimated by pellet group density, was greatest in mixed aspen-pine. Cattle use, estimated by chip density, was greatest in aspen and least in pine.*

Aspen (*Populus tremuloides*) is usually considered to be a subclimax species and is associated with a secondary seral stage in the western United States; rarely, it occurs as a climax species (Baker, 1918 and 1925). Stands of aspen normally develop on spruce-fir climax and on some pine sites following disturbance.

In recent years, some aspen stands in the Black Hills National Forest have been converted to ponderosa pine (*Pinus ponderosa*) to increase timber production. To determine the effect of this practice on white-tailed deer (*Odocoileus virginianus*) and cattle, the South Dakota Department of Game, Fish and Parks initiated a study in 1968 of deer and cattle use of aspen communities. Objectives of the study were to compare (1) overstories and understories of aspen, pine, and mixed aspen-pine, and (2) deer and cattle preference for these communities.

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The study was conducted under Federal Aid to Wildlife Restoration Project W-75-R in South Dakota. South Dakota Department of Game, Fish, and Parks, South Dakota State University, the U.S. Bureau of Sport Fisheries and Wildlife, and The Wildlife Management Institute cooperated in the research.

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Study Area and Methods

The Black Hills consist of an exposed crystalline core of igneous and metamorphic rock surrounded by eroded sedimentary formations of limestone and sandstone. Most of the soils are shallow, rocky, badlands soils modified by local conditions. Precipitation occurs chiefly during the growing season (April through September), and ranges from 17 inches per year in the south to 28 inches in the north (U.S. Dep. Agr. and U.S. Dep. of the Int., 1967).

Three areas (A, B and C) in the northern half of the Black Hills were studied from 1968 through 1970. Each area contained communities of aspen, pine, and mixed aspen-pine on gray wooded soils (Radeke and Westin, 1963). Soils of area A were of limestone origin with similar depths in the aspen, pine, and mixed aspen-pine. Soils of area B were also of limestone origin; however, soil depth was greatest in aspen and least in pine. Soils of area C resulted from breakdown of metamorphic rock and sandstones and were of similar depth.

Climax for all three study areas appeared to be ponderosa pine because all communities had various amounts of pine reproduction. Paper birch (*Betula papyrifera*), bur oak (*Quercus macrocarpa*), serviceberry (*Amelanchier alnifolia*), and white spruce (*Picea glauca*) also occurred.

Deer were present in the study areas for about 8 months each year; generally they were absent from December through March. Grazing by cattle was permitted from June 16 to September 20.

Criteria used to select study areas were: (1) that each contain one community of pure aspen, one of pine, and one consisting of a 50-50 mixture, and (2) the different communities be extensive enough to enable proper sampling without bias due to edge effect.

Nine belt transects (1,000 x 6 ft) were established, one in each community type in each study area, to measure overstory basal area, understory forage production, understory cover, and deer and cattle use.

Measurement of overstory basal area was made in 1970. A ten-factor wedge prism was used from the centerline of the nine belt transects, and square feet of basal area at diameter-

Table 1. Basal area (dbh[1] in ft²/acre) of overstory species for aspen, pine, and mixed aspen-pine communities in three study areas, Black Hills, 1970.

Area	Community	Aspen[2]	Pine[3]	Total
A	Aspen	95.9	3.3	99.2
	Mixed	32.2	122.0	154.2
	Pine	4.0	198.4	202.4
B	Aspen	73.4	25.2	98.6
	Mixed	25.4	124.4	149.8
	Pine	2.6	187.1	189.7
C	Aspen	61.4	10.0	71.4
	Mixed	30.5	66.3	96.8
	Pine	5.8	143.7	149.5
Average	Aspen	76.9	12.8	89.7
	Mixed	29.4	104.2	133.6
	Pine	4.1	176.4	180.5

[1] dbh = diameter-breast-height (4.5 ft)
[2] Includes birch, bur oak, and serviceberry.
[3] Includes spruce.

Table 2. Percent cover of major species of vegetation which occurred in the understory of aspen, aspen-pine, and pine communities.

Species	Aspen	Aspen-pine	Pine
Grasses and sedges	36.0	35.7	13.9
Clover (*Trifolium repens*)	20.8	15.0	2.5
Filbert (*Corylus cornuta*)	11.5	0.0	0.0
Oregon grape (*Mahonia repens*)	11.8	12.2	10.1
Vetchling (*Lathyrus ochroleucus*)[1]	11.8	4.8	2.1
Aster (*Aster* sp.)[1]	10.7	4.3	1.1
Pasture brake (*Pteridium aquilinum*)	8.2	4.2	0.2
Snowberry (*Symphoricarpos* sp.)	6.2	8.2	3.3
Meadowrue (*Thalictrum venulosum*)	4.8	1.0	0.2
Serviceberry (*Amelanchier alnifolia*)[1]	4.6	1.7	2.0
Bearberry (*Arctostaphylo uva-ursi*)	4.3	13.8	15.4
Wild strawberry (*Fragaria ovalis*)	3.3	2.2	0.8
Spirea (*Spiraea lucida*)	3.1	6.4	6.1
Wild rose (*Rosa* sp.)	2.8	2.1	1.5
Wild sarsaparilla (*Aralia nudicaulis*)	2.6	0.2	trace
Lupine (*Lupinus argenteus*)	2.4	1.4	0.4
Milk Vetch (*Astragalus* sp.)	2.3	1.8	0.2
Hop hornbeam (*Ostrya virginiana*)	2.0	0.0	0.0
American Vetch (*Vicia americana*)[1]	1.9	2.0	0.6
Yarrow (*Achillea lanulosa*)	1.8	5.0	1.5
Wild bergamot (*Monarda fistulosa*)	2.9	3.2	0.6
Juniper (*Juniperus* sp.)	0.0	1.3	3.0
Arnica (*Arnica cordifolia*)	0.8	1.8	0.1
Others[2]	16.8	13.8	3.1
Total	172.6	140.3	68.6

[1] Four preferred food species in the northern Black Hills (Schneeweis, 1969).
[2] Includes 37 other species with less than 5% of total in all study areas.

Table 3. Shrub, forb, and grass production (lb/acre, air-dried) in aspen, mixed aspen-pine, and pine in three study areas, Black Hills, 1968-69.

Area	Community	Shrub	Forb	Grass	Total
A	Aspen	229	207	56	492
	Mixed	127	145	47	319
	Pine	146	18	12	176
B	Aspen	213	195	64	472
	Mixed	171	60	10	241
	Pine	128	38	20	186
C	Aspen	179	200	424	803
	Mixed	159	193	333	685
	Pine	189	67	139	395
Average	Aspen	207	201	181	589
	Mixed	152	133	130	415
	Pine	154	41	57	252

Fig. 2. *Understory cover of most species was least in the pine communities. (U.S. Forest Service photo by Kieth E. Severson)*

breast-height (dbh) for each overstory species was recorded.

Annual understory forage production in pounds per acre air-dried for shrubs, forbs, and grass was determined by clipping annual growth from ten, 9.6 square-foot plots, located at random in each belt transect.

Percent cover for understory species was estimated using 50 randomly selected 1.0 square-foot plots along the centerline of each belt transect. Cover estimates were made for each species with the exception of grasses and sedges which were treated as a group.

Use of aspen, pine, and mixed aspen-pine by deer and cattle was estimated using counts of deer pellet groups (Bennett et al., 1940) and cattle chips (Fuller, 1928) found on the nine belt transects.

Results and Discussion

Overstory Basal Area

Analysis of variance indicated a difference ($P<.01$) in basal areas between aspen, mixed aspen-pine, and pine, and also between study areas A, B, and C. Mixed aspen-pine appeared visually as consisting of 50% aspen and 50% pine; however, the average basal area was 29.4 square feet per acre for aspen and 104.2 square feet per acre for pine (Table 1). Overstory basal area was least for the aspen community, intermediate for the mixed aspen-pine, and greatest for the pine community.

Understory Composition

Fifty-nine species of shrubs and forbs were found in the communities; 54 were in the aspen, 49 in mixed aspen-pine, and 39 in pine.

Cover for understory species was greatest in aspen, intermediate in mixed aspen-pine, and least in pine (Table 2). The cover of most species was greatest in the aspen stands (Fig. 1); bearberry, spirea, and juniper were notable exceptions with greater cover in the pine stands (Fig. 2).

Four preferred summer deer-food species (aster, serviceberry, vetchling, and American vetch) in the northern Black Hills (Schneeweis, 1969) generally decreased in abundance

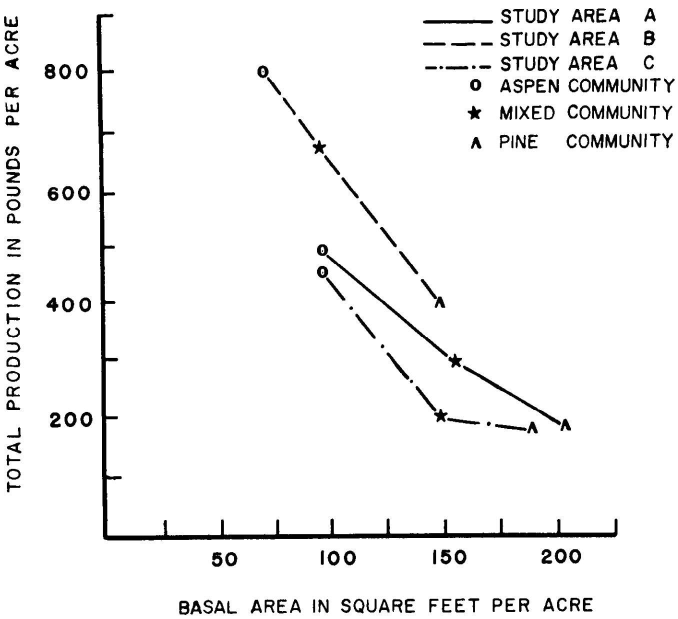

Fig. 3. *Total understory production (air-dried forage) as related to overstory basal area.*

from aspen to pine communities (Table 2). The relative abundance of these preferred species suggests that aspen stands should be primary feeding areas.

Understory Production

Total production was significantly different ($P<.01$) between communities, with greatest production in aspen and least production in the pine communities (Table 3). Also, the proportion of the total production in shrubs, forbs, and grasses was significantly different ($P<.01$) between communities. Generally, shrub production in the mixed aspen-pine understories did not change as much as forb and grass production. While shrub production was 25% less in the pine than aspen understories, forb and grass production was 80% and 69% less, respectively.

Differences in total understory production was no doubt influenced by different overstory basal areas; basal area of aspen overstories was least and that in pine was greatest (Fig. 3). Pase (1958), Pearson (1964), and Jameson (1967) each studied pine communities with variable basal areas and found that understory production was inversely related to overstory production.

Deer and Cattle Use

Counts of deer pellet groups and cattle chips made in 1969 and 1970 were used to estimate preference for the community types by deer and cattle.

Analysis of variance indicated more ($P<.01$) use by deer of mixed aspen-pine than of other communities (Table 4). Aspen communities were used more ($P<.05$) than pine communities. The high counts associated with mixed aspen-pine communities suggest that use by deer was not governed by single factors such as overstory type, overstory density, or understory production, but by a complex of habitat factors.

Number of cattle chips was different ($P<.05$) between communities and was correlated ($P<.01$) with understory grass production (r = 0.95). Other investigators have also shown a close relationship between grass production and cattle use (Julander, 1955; Reynolds, 1966).

Table 4. Number of deer pellet groups and cattle chips found on belt transects for aspen, pine, and mixed aspen-pine in three study areas, Black Hills, 1969-70.

Study area	Community	Deer pellet groups	Cattle chips
A	Aspen	50	9
	Mixed	60	11
	Pine	15	2
B	Aspen	26	22
	Mixed	39	5
	Pine	27	4
C	Aspen	30	53
	Mixed	53	50
	Pine	31	15
Average	Aspen	35	28
	Mixed	51	22
	Pine	24	7

Conclusions

Among the aspen, mixed aspen-pine, and pine communities studied, aspen appeared to represent a subclimax species and ponderosa pine the climax species. Overstory basal areas were least in the aspen stands and greatest in the pine stands. Total understory production was greatest in the aspen communities and least in the pine communities. Understory production was influenced by overstory basal area; however, other factors that we did not study may also influence understory production.

Deer preferred the mixed aspen-pine stands, followed by aspen, and pine. Preference was not governed by single habitat factors such as overstory type, overstory density, or understory production, but by an interrelationship of those factors. Cattle preferred the aspen communities, followed by mixed aspen-pine, and pine, with preference directly related to understory grass production.

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Sheep Production on Natural Pasture by Roaming Bedouins in Lebanon

A. N. BHATTACHARYA AND M. HARB

Highlight: *Studies have been conducted with 2,589 Awasi sheep belonging to nine family groups having an average of 11 members each to investigate the husbandry practices and production of livestock by roving Bedouins in Lebanon. The natural pasture plants grazed by the sheep were identified and analyzed for chemical composition. The growth rate of lambs and the yield and composition of ewe's milk were also determined in a selected sheep population. The study shows that natural pastoral resources contribute significantly to sheep production by the Bedouins. The traditional methods used under the circumstances do not seem to impede the yield of animal product.*

The term *Bedouin* has been derived from the Arabic word *Badawi* which means: "Those who live in the desert." Bedouins are pastoral nomads involved in nonsedentary animal husbandry. They roam seasonally in a cyclical or rhythmatic course in search of pastures and water, with the entire human group accompanying the flocks and herds along winter and summer grazing grounds following more or less fixed routes. The use of land in pastoral nomadism is ecologically acceptable and capable of continuing for centuries without depleting the basic vegetation resources. The marginal land used in this practice is otherwise inaccessible. Intensive grazing, however, can convert this land of low productivity into a completely unproductive area. In terms of land usage, Barth (1960, 1961) finds it a maximizing system for the support of human societies and their flocks. He shows conclusively that the standard of living of Iranian pastoralists is well above that of the sedentary villagers past whose villages they migrate. About 50 million sheep are being raised every year by Bedouins, out of a total of 154 million in the Near Eastern countries consisting of Afghanistan, Iraq, Iran, Syria, Lebanon, and Jordan (Kolding and Kofod, 1970). Methods of animal production practiced by Bedouins are practically unknown to the outer world. Furthermore, studies on the production parameters of Bedouin animal industry are seriously lacking.

The objective of this preliminary study conducted in central Lebanon were: (1) to describe the sheep population raised and the husbandry practices followed by Bedouins; (2) to identify the plants and weeds grazed in natural pastures; (3) to determine the chemical composition of pastures sampled from different natural grazing grounds used by Bedouins; and (4) to investigate growth rate and milk production in Bedouin sheep flocks.

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Methods and Materials

Interview survey

Nine groups of Bedouins roaming in different areas of central Lebanon were interviewed. The average number of members in each group was 11. The total number of sheep owned by these groups was 2,589. A questionnaire was developed to obtain information regarding composition and characteristics of the sheep population, methods of feeding, breeding and management practiced, and livestock products and their economic return. The main subject matter covered in the questionnaire is shown in Table 1. Each group was approached properly, satisfying their tribal customs. After the acquaintance was established, the head of each group, accompanied by his group members, was questioned. Each group was contacted at certain intervals as they moved from place to place during a 5-month period from April to August, 1970. During this period the same questions were repeated more than once, and any disparity in the answer was clarified.

Pasture studies

Samples of plants were collected in plastic bags from different natural pastures used by the Bedouins under study. All samplings were taken while the sheep were grazing. A number of samples were collected from the grazing ground in a particular location. As each Bedouin group moved, the new pastures grazed were also sampled. Some samples contained one plant variety, while others were mixed. After each sample collection, a few intact plants were pressed for preservation for later identification. The remaining portion was dried at 70°C for 24 hours and then ground. A sample of

Table 1. Form showing main subject areas of the questionnaire.

Date:	Camp location:	Next camp location:
1. Name of the tribe ("Qabila", "Fakhth", "Aila", "Bayt", etc.)		
2. No. of people living together in the camp (Adult males, females, children)		
3. Total no. of animals (Growing lambs, mature rams, and ewes)		
4. Breed of sheep (Varieties, etc.)		
5. Growing lambs (Weaning and marketing age/wt, selling price, lamb mortality, stock replacement, etc.)		
6. Mature ewes (Adult wt, breeding season, no. of pregnant ewes, birth wt, milk yield/lactation, etc.)		
7. Milk (Daily production and price, marketing problems, etc.)		
8. Breeding rams (Selection method, time of culling, breeding problems, etc.)		
9. Feeding and management (Countries roamed, best pasture time, grazing hours, pasture cost, watering problems, other feeds, etc.)		
10. Wool (Yield/year, price/kg, shearing frequencies, etc.)		

Fig. 1. *A flock of ewes tied face to face in rows for milking.*

Fig. 2. *A flock of sheep at water.*

the ground forage sample was then analyzed for proximate components, including calcium and phosphorus, following the methods outlined by A.O.A.C. (1966).

Sheep production

The growth rate of lambs, their adult weight, and yield and composition of ewe milk were determined in a selected sheep population in the Bedouin flocks. A mobile unit equipped for various measurements visited the Bedouins at intervals during the period of study as the nomads moved from place to place. Daily weight gain of twenty 4-month old lambs selected at random was studied during a 3-month period. About twice that number of lambs were initially included in the growth experiment; but since many lambs, especially the males, were sold during the later part of the experiment, the data were not incorporated. The lambs were ear-tagged at the beginning of the experiment. Body weights of the numbered lambs were recorded approximately every fortnight. The adult weights of 12 rams and 42 ewes were also recorded. Sixteen milking ewes were selected at random and their daily milk yield recorded. Milk samples were also taken for fat and protein determinations.

Results and Discussion

Information regarding husbandry practices and sheep production as obtained from the Bedouins is shown in Table 2. The ewes were bred during the months of June (late) and July, when the number of hours of daylight starts to decline. Thus late summer and a part of winter (Sept. to Jan.), when pasture is scarce, corresponds to the dry period of the ewe flocks. In drought months the ewes are sometimes late in coming to heat. On the average, three breeding rams served each 100 ewes. Approximately 90% of the ewes in the flocks seemed to be pregnant following this natural breeding practice. The average weaning age of lambs ranged between 2 and 4 months, and the weaning age for the entire sheep population studied was 75 days. Lambs kept for breeding purposes were weaned at the upper age range margin. Within 1 month after weaning, almost all the lamb crops were sold at a price comparable to urban market price. The mortality of new-born lambs was about 9%.

After lambing in January, when the pastures are not yet green, the nursing ewe flocks are usually undernourished and the tail fat thins out. Some Bedouin groups practice concentrate-feeding during the winter months, depending upon cost and availability of the concentrates. The best months of pasture seem to be from April to July. Only the ewes in their third or fourth month of lactation and the replacement stock, consisting of female and breeding ram lambs can take advantage of pasture, as most of the ram lambs are sold soon after weaning. If the ram lambs were kept for 3 more months until after the peak pasture period, a higher monetary return could be expected, as will be seen from our growth study.

Table 2. Bedouin husbandry practices and sheep production in nine family camps averaging 11 members per family.

Item	Amount[1]
Total no. of sheep	2589
Percent ewes of total population	67
No. of breeding rams per 100 ewes	3 (2–4)
Months of breeding	June and July
Avg weaning age	75 days (60–120)
Avg marketing age	90 days (75–150)
Price/kg live weight	3 L.L. (2.5–3.5)
Percent lamb mortality	9 (5–11)
Avg lactation period (including nursing period)	250 days
Avg daily milk yield for 150 days (after weaning of lambs)	1.5 lb
Avg price/kg milk[2]	50 L.P.
Months of good pasture	April–July
Avg rental cost for pasture (when paid)	4 L.L./1000 meters^2
Avg grazing hours per day	10.5 (10–11)
Ingredients of winter feeding	Barley, bran, beet pulp, tibn (straw)
Watering sources	Springs and wells

[1] Range in parentheses for some items.
[2] One dollar (U.S.) = 3.25 L.L. and 1 L.L. = 100 L.P.

The average length of lactation of the ewe flocks was about 8 to 9 months. This could be subdivided into three phases: 1) The first phase comprised 2 to 3 months of nursing after lambing. Most ewes in this phase were fed a concentrate feed mixture and produced an average of 2 pounds of milk per day. 2) The second phase of lactation started when the lambs were weaned and the ewes had access to a good pasture, which continued for a period of 3 months (April to June). The milk production increased, the average yield being 2.5 pounds per day during the whole period. 3) The third phase, covering the following 2 to 3 months (July to September), showed a period of gradual decline in milk production, with the ewes eventually drying at the end of the period. The milk production during this period was about 1 pound a day per sheep.

Thus the average milk production during a 150-day period after weaning of lambs was approximately 1.5 pounds per day. Ewes were milked twice daily (Fig. 1). Some Bedouin groups practice one evening milking, starting at the beginning of the second month of lactation. They keep their lambs with the ewes for half day while removing the lambs from the ewe stock for the remaining half.

It is apparent from the information that at the onset of pasture, even though the ewes are at their third or fourth month of lactation, there is an increase in milk production. Under normal farm feeding conditions the ewes have long passed their peak of lactation by this time. A higher milk production per lactation might be possible if the lactating ewes could take advantage of the pasture at an earlier time, thereby starting with a higher daily yield. Breeding ewe stock a month or two later might improve the total milk production.

Sheep milk is very popular in Lebanon for the manufacture of various milk products. The price of 0.5 L.L. (15 cents U.S.) per kg of milk sold by Bedouins was comparable to that found in the urban market.

The majority of the Bedouins moved onto the neighbouring country, Syria, during the winter months. Some paid a rent for the grazing ground used, as usually the hilly marginal lands are owned by people and are not government properties. Some Bedouins seeded the pasture before moving on to the next location, usually with barley and vetch. None of the Bedouin groups had any trouble finding sources of water. Available springs and wells were sufficient for watering their sheep (Fig. 2).

The plants identified in the natural pasture included grasses like *Bromus tectorum, Poa annua, and Lolium* sp.; legumes such as *Medicago rigidula, Lathyrus cicera, Trifolium* sp., *Vicia narbonensis,* and *Vicia* sp.; and other species such as *Cardaria daha, Coronilla scorpoides, Galium* sp., *Geranium dissectum, Juncus* sp., *Lampocarpus* sp., *Lupinus pilosus, Metricaria chamomilla, Mentha longifolia,* and *Taraxacum* sp. Some legume plants in Lupinus sp. are sometimes poisonous due to a high content of cyanogenetic glucoside. Plants like *Mentha longifolia* were not only very tough in texture but also had intense aroma. The chemical composition of plant samples collected from various grazing grounds are shown in Table 3. The crude protein content of the pastures on a dry matter basis was generally rather high, the average value being approximately 10%. Even though the crude fiber value was as high as 36% on a dry basis in some samples, the usual values were lower. Calcium and phosphorus contents of the natural pastures were appreciably high. Grazing of sheep in a natural homogeneous pasture of *Mentha longifolia* is shown in Figure 3.

Table 3. Chemical composition (%) of pastures.

		Percent nutrient component (dry basis)						
Locality	Sample number[1]	Crude Protein	Crude Fiber	Ether ext.	Ash	NFE[2]	Ca	P
Bednayal	1	11.4	13.0	1.9	15.3	58.4	2.77	0.15
Bednayal	2	14.5	18.6	2.3	11.5	53.0	1.74	0.24
Deer Al Ghazal	1	17.1	15.0	1.2	12.4	54.3	1.45	0.35
Deer Al Ghazal	2	15.1	15.6	1.9	14.8	52.9	2.34	0.35
Deer Al Ghazal	2	12.0	25.3	1.9	12.5	48.4	1.56	0.25
Hazzin	1	18.6	15.8	2.3	19.2	44.1	3.45	0.21
Hazzin	2	5.3	36.2	1.1	7.3	50.1	0.50	0.15
Hazzin	3	2.3	22.3	0.7	14.3	60.5	1.25	0.03
Housh Sneid	1	3.9	26.6	0.8	7.3	61.4	0.61	0.10
Housh Sneid	2	8.0	21.2	2.0	6.5	62.3	0.76	0.15
Housh Sneid	3	12.1	17.1	1.1	10.1	59.7	1.94	0.21
Sarain		5.9	32.6	2.1	7.3	52.0	1.12	0.11

[1] Number of sample from particular area.
[2] NFE = Nitrogen free extract.

The results of the sheep production study conducted are shown in Table 4. The average daily gain of the month-old lambs during a 3-month period was about 0.42 pounds per day. The growth rate of Awasi lambs recorded in a previous study (Wardeh, 1969) under ideal feeding and farm management conditions was 0.48 pound and 0.39 pound, respectively, for males and females during a period of 120 days after birth. Considering a mixed population with more ewe lambs than ram lambs, the average growth rate obtained by Bedouins is not lower than that obtained under sedentary farm conditions. The reason for a higher proportion of ewe lambs in the final growth data was that the growth record of many ram lambs could not be completed because some of the ram lambs were sold by the Bedouins before the completion of experimental growth period. The adult weights of Awasi rams and ewes were on the upper margin of the range (132-198 pounds for rams and 66-110 pounds for ewes) reported by Mason (1967). The milk yield per day during a period of 3 months after weaning averaged 2.25 pounds with average fat and protein percentages, respectively, of 6.8 and 6.5. The reported yield value for the Awasi breed when fed under ideal conditions is 125 kg for a 150-day period (Mason, 1967); Finci, 1957; Khoury, 1965). The fat content varied greatly within a range of 5.8 to 7.5%, but the fat content of most samples was along the upper margin of the range.

The result of this preliminary study indicates that the Bedouins or semi-Bedouins raising sheep in the natural pasture lands of Lebanon and Syria contribute significantly to the animal industry of the country. The husbandry practices and methods followed, though traditional, are efficient for economic production and protection of sheep. Even though the yield and quality of the produce in this limited study does not seem to be very much lower than that produced under ideal farm conditions, an overall improvement could be expected from modifying certain practices to suit the existing environmental conditions. However, extensive studies should be conducted before any change is recommended.

Table 4. Adult weight, daily gain, milk yield, milk yield, and composition.

Item	Amount
Avg adult wt (lb)	
Breeding ram	180
Ewe	108
Avg daily gain (lb)	0.42
Avg daily milk yield (lb)	2.4
Avg milk fat (%)	6.8
Avg milk protein (%)	6.5

Summary

Studies have been conducted with 2,589 Awasi sheep belonging to nine family groups, averaging 11 members each, to investigate the husbandry practices and problems of livestock production by roving Bedouins in Lebanon. The natural pasture plants grazed by the sheep were identified and analyzed for chemical composition. The growth rate of lambs and the yield and composition of ewe's milk were also determined in a selected sheep population.

The weaning age of lambs ranged from 2 to 4 months. Within 1 month after weaning, the lambs were marketed. The ewes were bred during the months of June and July, and the number of pregnant ewes seemed to be about 90% of the ewe population. After the ewes were milked twice daily for a 4- to 5-month lactation period milk production declined. The average milk yield obtained was 1.5 pounds per day. A majority of the Bedouins included Syrian land along their route of grazing and paid for the pastures they used. Some did seed the pasture and none had any problem of watering their sheep.

A variety of plants made up the forage on the natural pastures. Their chemical composition showed a wide range of

Fig. 3. *A flock of sheep grazing in a natural pasture of* Mentha longifolia.

variation. The ranges of protein and fiber content on a dry matter basis were, respectively, 2.1-19.5% and 11.2-36.2%. The average daily gain of the 24-month old lambs during a 3-month period was 0.42 pound. The average adult weight of the male (breeding ram) and female sheep were 180 and 108 pounds, respectively. The yield of milk per day per ewe during the 3-month post-nursing recording period was 2.4 pounds. The milk fat content ranged from 5.8 to 7.6%, the average being 6.8.

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Use of Molasses Containing Urea as a Supplement to Pangolagrass Pastures in Northeast Mexico

M. H. BUTTERWORTH, E. L. AGUIRRE, A. C. ARAGON, AND D. L. HUSS

Highlight: *Supplements of molasses, molasses + 3% urea, and molasses + 6% urea at a level of approximately 1 kg/head/day on pangolagrass pasture during the winter and spring months resulted in significantly increased weight for ¾ Zebu x ¼ Criollo bulls. Urea was more effective during the winter months when forage availability was at its lowest, than during the spring months. It is suggested that the use of pangolagrass pasture with molasses and urea supplementation when appropriate could significantly increase production from rangeland.*

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Using statistics provided by FAO (1967), it may be calculated that about 6 million metric tons of molasses are produced yearly in the Latin American area. Only a limited quantity of this molasses is used industrially and thus a large amount is available for animal feeding.

Molasses has been used both in the feeding of intensively fed cattle (Preston et al., 1964) and as a supplement to pasture during periods of scarcity of forage during cool or dry conditions (Carrera et al., 1963).

In increasing the production of beef from tropical and subtropical grasslands, both from "tame" pastures and range, it is important to investigate how production per unit of surface area may be increased by correcting seasonal deficiencies in both quantity and quality of forage. The object of this experiment was to investigate the use of molasses as a supplement of energy, combined with various levels of urea as a supplement of nonprotein nitrogen, on pangolagrass (*Digitaria decumbens* Stent.) pastures during winter and spring when grass growth rate was reduced.

Material and Methods

This experiment was carried out in the district of Aldama in the state of Tamaulipas, N. L., Mexico. Pangolagrass pastures have been established in small areas with favourable precipitation in a zone which can be considered basically range. The climate is generally humid (629 mm annual rainfall), but there is a definite seasonal decline in pasture productivity from November until March. Four pastures each of approximately 8 hectares were used. These were even stands of pangolagrass which had been established for some years. During the previous year, the pasture had been more or less constantly grazed and no fertilization or other conditioning had been practiced.

One group of 12 bulls, approximately 3/4 Zebu x 1/4 Criollos between 12 and 18 months of age and weighing approximately 240 kg, was allocated at random to each of the four pastures. Each bull was identified by both ear tags and hot-iron brands, and each was free from parasites prior to the study by use of a systemic parasiticide.

The research treatments were: grazing with no supplement, grazing plus approximately 1 kg per day of molasses supplement, grazing plus 1 kg per day of molasses containing 3% urea, and grazing plus 1 kg per day of molasses containing 6% urea. Urea was dissolved in the minimum amount of water necessary to guarantee even mixing, and the weight of the molasses fed was adjusted accordingly.

The stocking density was equivalent to approximately 1.5 animals per hectare, a value which reflected common management practice in the area. After a 14-day preliminary period to accustom the animals to the experimental conditions, they were weighed and allocated, again at random, to treatments.

Molasses or molasses with urea was fed in open troughs and put out at 3-day intervals in quantities necessary to proportion approximately 1 kg per head per day. This method insured that all animals had opportunity to eat at the troughs. A mixture of salt and bonemeal in the proportion of 1:1 was available free-choice at all times.

Animals were weighed at 28-day intervals. The experiment lasted a total of 112 days from February through May. At the date of each weighing, groups were changed from one pasture to another in such a way that each group spent one period in each pasture, thus minimizing any possible differences among pastures.

Samples of grass were taken from each pasture during each period for analysis of protein content.

Results

Values for initial and final weights, daily gain during the various periods, and actual molasses consumption are given in Table 1. In view of the disparity of the initial weights, a covariance analysis was used to compare weight gains. Significant differences were demonstrated to exist among treatments. Groups fed molasses alone and molasses + 6% urea gained significantly more weight ($P > 0.05$) than the group without supplementation and that fed molasses + 3% urea; the apparently anomalous situation of the latter group was entirely due to low gains during the third period. When the results for this period were not considered, this treatment was similar to the other supplementary treatments. Gains per head of 578, 765, 785, and 779 g per day for animals on treatments 1, 2, 3, and 4, respectively, was significantly superior to that of unsupplemented animals.

A highly significant difference was found to exist among weight gains attributable to period. Mean weight gains for the four periods were 565, 689, 809, and 924 g/day for the first, second, third, and fourth periods, respectively. No interaction could be demonstrated between effects due to periods and those due to treatments.

The mean protein content of the grass (expressed on a dry matter basis) was 3.6%, 3.8%, 4.5%, and 4.4% for the first, second, third, and fourth period, respectively.

Discussion

In general, the only exception being the treatment involving molasses + 3% urea during the third period, gains were better for the supplemented groups than for the unsupplemented group. This difference amounted to an average value of 197 g per head per day. The exception previously mentioned may be explained by the fact that heavy rains occurred during this period and the pasture in which the animals fed molasses + 3% urea were grazing was slightly flooded, reducing forage availability and thus intake.

Results are in agreement with those of Carrera et al. (1963), who showed that supplementation with molasses was effective during periods of shortage of forage but not when abundant forage was available. Similar results were obtained by Chapman et al. (1965) using beef cows in Florida and by Chapman et al. (1961) working with steers.

During the first period there was a marked indication that growth rates were greater with increasing levels of urea supplementation; however, this tendency reached statistical significance only at the 10% level when the results for this period were analyzed alone. The mean value for protein content of grass sampled during this first period was lower than the mean literature values of 5.6% for pangolagrass subjected to constant grazing (Butterworth, 1968). Using the equation developed for digestibility of the protein of pangolagrass (Butterworth and Diaz, 1970), it may be calculated that the apparent digestibility of this fraction was clearly insufficient to maintain optimum growth rate. Some effect of supplementary nonprotein nitrogen was therefore to be expected during this period, although the actual protein ingested by the animals was probably higher than that indicated by the analysis because of selective grazing. Weight gain during subsequent periods was apparently limited by energy rather than protein provision.

Increased weight gains as the experi-

Table 1. Starting and final weights, daily weight gains, and supplement consumption of bulls grazing pangolagrass supplemented with molasses, molasses + 3% urea and molasses + 6% urea during four periods of 28 days each.

Treatment	Control	Molasses	Molasses + 3% urea	Molasses + 6% urea
Starting weight (kg)	245.4	235.4	238.9	242.3
Final weight (kg)	315.0	325.3	321.5	334.9
Daily gain (gm)				
1st. period	388	528	603	740
2nd. period	564	691	864	639
3rd. period	751	925	592	968
4th. period	781	1066	888	960
Overall*	621 a	802 b	736 a	826 b
Consumption of supplement (gm)		889	901	799

*Values bearing the same letter are not significantly different from each other.

ment progressed were presumably attributable to augmented availability of forage. In order to investigate factors influencing growth of forage, mean weight gains for each period were correlated with the corresponding mean ambiental temperatures (15.7°C, 20.1°C, 24.1°C, and 27.5°C for the first, second, third, and fourth periods, respectively). The correlation coefficient obtained was 0.998 ($P<0.01$) with a value for the regression coefficient (b) of 30.3 g. This indicated that gain in weight per day increased 30.3 g for every 1°C increase in temperature. No relation was discernible when similar calculations were made with precipitation data. It may therefore be concluded that during the period in which the present study was carried out, the growth rate of the grass was limited by temperature rather than by moisture. This is in agreement with results obtained by McCloud et al. (1957), who showed that the growth of pangolagrass was considerably reduced by a temperature change from 21°C to 10°C.

There was some indication that intake of molasses + 6% urea was somewhat lower than that of molasses + 3% urea, although this tendency was not marked. Similar results have been reported by Beames (1960), who used molasses/urea mixtures as supplements to pasture and by Preston et al. (1967), who used similar mixtures as a supplement to a grain diet.

Although it is often considered that there is little relation between range and "tame" pastures, the authors feel that the latter can be used as valuable adjunct to increase the efficiency of adjoining rangeland. Specific applications could not only include raising calves produced in cow/calf operations after weaning with subsequent grass fattening but could also provide a useful reserve of forage for the reproducing herd during critical periods.

An economic evaluation of the data indicated that supplementation in all cases studied would be expected to be beneficial under general market conditions prevailing in Mexico.

Summary

Forty eight young 3/4 Zebu x 1/4 Criollo bulls were used in an experiment to determine the effect of molasses, molasses + 3% urea, and molasses + 6% urea at a rate of approximately 1 kg per head per day as a supplement to pangolagrass pasture with a stocking density of 1.5 animals per hectare. The study was carried out in northeast Mexico during the months of February through May, a period when pasture growth is reduced. Significant improvement in growth rate was caused by all supplementary treatments (with the exception of molasses + 3% urea during the third month), and it was concluded that such supplementation may be recommended during periods of reduced forage availability. During the first period, when forage availability was at its lowest, there was an indication that animals responded to increased levels of urea, although this tendency did not reach significance. No beneficial effect attributable to urea was noticeable during subsequent periods.

A significant increase in growth rate of the cattle took place as the experiment progressed; the correlation between mean ambiental temperature and weight gain for the corresponding periods was highly significant, the regression of growth rate on temperature increase being 30.3 g per day per degree centigrade increase. It was concluded that during the period of the experiment, temperature was more limiting to grass growth than was precipitation. Findings were discussed with reference to other studies published in this field.

It is suggested that the use of such supplementation of pangola with molasses can provide a useful additional source of forage for surrounding range areas in certain parts of northeast Mexico.

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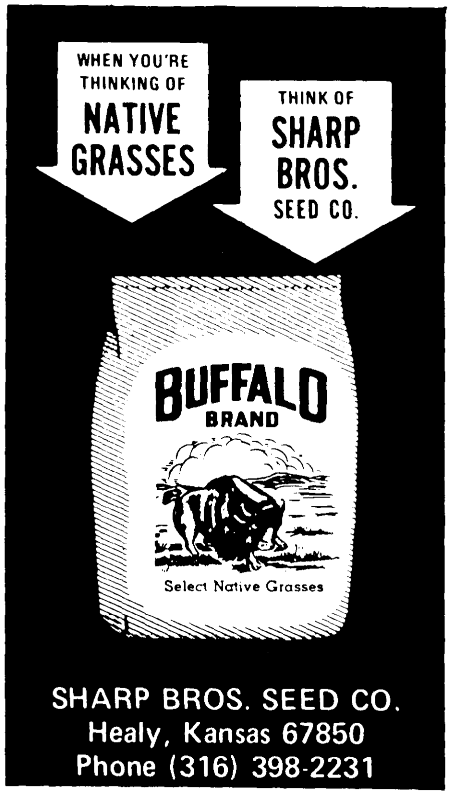

Influence of 2,4-D and 2,4,5-T on In Vitro Digestion of Forage Samples

A. E. SMITH

Highlight: *The influence of 2,4-D [(2,4-dichlorophenoxy) acetic acid] and 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] on in vitro digestion of dried ground corn silage (*Zea mays *L.) and bermudagrass (*Cynodon dactylon *L.) foliage was determined using a modification of the Tilley and Terry method for determining in vitro dry matter digestibility of forage plants. Neither herbicide influenced the digestion of plant samples when treated with a herbicide concentration range of* 10^{-8} *to* 10^{-4} *M. Solutions containing* 10^{-4} *M of either herbicide did not influence the growth of microbial populations in incubated rumen liquor. The influence of rumen microorganisms on degradation of 2,4-D and 2,4,5-T was also investigated. Samples containing sucrose or plant material, buffered rumen liquor, and* 10^{-4} *M concentrations of either herbicide were incubated for 10 day periods. Data from periodic quantification of herbicide remaining in the samples indicated that neither herbicide used in these experiments was degraded by the rumen microorganisms. Results indicate that: (1) 2,4-D and 2,4,5-T do not alter the rumen microbial functions or development and (2) these herbicides are not readily degraded in the rumen by the rumen microorganisms.*

For almost three decades 2,4-D [(2,4-dichlorophenoxy) acetic acid] has provided the American farmer with an effective and economical means of controlling broadleaf weeds in crops and pasture lands. The related compound, 2,4,5-T, [(2,4,5-trichlorophenoxy) acetic acid] was introduced to help in the control of brush and more resistant weeds in pastures and rangeland. Recently, use of these herbicides has met with much adverse publicity from certain ecologists and environmentalists. They have been concerned that ingestion of these herbicides from treated pastures and ranges could result in contamination of the meat, making it unfit for human consumption.

Many scientists have undertaken research to determine the magnitude of herbicide contamination in by-products from animals fed varying amounts of these herbicides (Clark et al., 1964; Clark and Palmer, 1971; Leng, 1972). In general, they have concluded that: (1) residues of phenoxy herbicides are not likely to exceed 300 ppm in or on forage immediately after treatment with these herbicides at recommended rates for control of weeds and brush in pastures and rangelands; (2) generally, such residues decline rapidly with a half-life of 1 to 2 weeks depending on geographic location; and (3) residues of phenoxy herbicides and their phenolic moities are not likely to occur in milk, meat, or fat.

Previous studies have indicated that sheep and cattle can tolerate rather large quantities of 2,4-D salts and esters for extended periods of time (Radeleff and Bushland, 1960). However, whether 2,4-D is metabolized, stored, or excreted unchanged from sheep or cattle has received little attention. Clark et al. (1964) found that following the oral administration of 2,4-D-^{14}C, the majority of the activity had passed through the blood within a 24-hour period and by the end of 28 hours post treatment 90% of the 2,4-D-^{14}C was recovered in the sheep urine. Similar results have been reported for 2,4,5-T (Clark and Palmer, 1971; St. John et al., 1964). Little research has been accomplished on the influence of these herbicides on the digestive functions and development of the rumen microorganism or on the influence of these microorganisms on the degradation of 2,4-D and 2,4,5-T over prolonged periods of time.

This study was undertaken to determine: (1) the influence of these herbicides on the in vitro dry matter digestibility (IVDMD) of corn (*Zea mays* L.) and bermudagrass (*Cynodon dactylon* L.) forage samples, (2) the influence of 2,4-D and 2,4,5-T on rumen microbiota growth, and (3) the in vitro degradation of 2,4-D and 2,4,5-T by rumen microbiota.

Methods and Materials

Experiment 1.

The influence of 2,4-D and 2,4,5-T on the IVDMD of ground corn and bermudagrass plant samples was determined by using a modification of the Tilley and Terry two-stage method for determining the IVDMD of forage crops (Tilley and Terry, 1963). Separate half gram samples of dried bermudagrass foliage and samples of equal portions of ear, leaf, and stem material from ensilage corn were ground to pass through a #40 mesh screen. The plant foliage samples were incubated with 45 ml of buffered rumen liquor in 50-ml centrifuge tubes. The rumen liquor used in all the experiments was removed, through a permanent fistula, from a mature steer maintained on a grass diet for the duration of these experiments. In treatments containing 2,4-D and 2,4,5-T, quantities of a buffered (pH 6.9) solution of each technical grade herbicide were added to give final herbicide concentrations of 0, 10^{-8}, 10^{-7}, 10^{-6}, 10^{-5}, or 10^{-4} M in the buffered rumen liquor. A sample consisted of a single concentration for each herbicide. Herbicide solutions were added preceding the addition of the buffered rumen liquor. This experiment was repeated twice and the data analyzed by the appropriate analysis of variance test (Steele and Torrie, 1960).

Experiment 2.

In an attempt to determine the influence of 2,4-D and

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2,4,5-T on the growth of microbiota in rumen liquor, an experiment was conducted using 0.2 g sucrose to replace the plant material and only the first stage of the two-stage technique for the IVDMD of forage crops. Treatments consisted of 10^{-4} M 2,4-D or 2,4,5-T and no herbicide. The herbicide treatments were conducted the same as in experiment 1. At 0, 2, 4, 7, 9, and 11 days after adding the herbicides, quadruplicate samples were removed from the incubator and centrifuged for 15 min at 1800x*g*. After discarding the supernatant, the insoluble residue was washed once with 40 ml distilled water, centrifuged, and the supernatant discarded. The insoluble residue was dried at 88°C for 48 hours and the dry weights of the residue calculated. This experiment was repeated twice and all data were statistically analyzed by the appropriate analysis of variance tests.

Experiment 3.

The purpose of this experiment was to determine the influence of the rumen microorganisms on the degradation of 2,4-D and 2,4,5-T. Forty-five ml of buffered rumen liquor were placed into 50 ml centrifuge tubes containing 0.5 g dried ground bermudagrass foliage or in tubes without the plant material. The latter series of treatments were included to determine the influence of forage material on the microbial degradation of these herbicides. Treatments consisted of final concentrations of 0 or 10^{-4} M 2,4-D or 2,4,5-T. The sample tubes were incubated at 38° C throughout the experiment. At 0, 2, 4, 6, 8, and 10 days after beginning the experiment, quadruplicate samples from each treatment were removed from the incubator. The samples were centrifuged at 1800x*g* for 15 min and 10 ml aliquots of supernatant were removed from each sample tube for herbicide quantification. Herbicide remaining in the 10 ml aliquots was extracted, methylated, and quantified by a method similar to that used by Smith (1972). The 10 ml aliquots were acidified with 1 N HCl. The herbicide was extracted from the acidified solution with two 20 ml aliquots of diethyl ether and the ether evaporated in an 80° C water bath. The herbicide was esterified with 6 ml of BF_3/methanol (125 g/L) (Merkle and Davis, 1966). Methyl esters of the herbicides were taken up, quantitatively, in hexanes and quantified using an F&M 700 gas chromatograph equipped with a nickel-65 electron capture detector. A 1.8 M spiral glass column packed with 80-100 mesh chromosorb W coated with 4% SE30 was used. Flow rate of the argon/methane (95/5 percent) carrier gas was 40 ml/min. Column, injection port, and detector temperatures were 200, 250, and 230° C, respectively. The experiment was repeated twice, and the data were statistically evaluated by the appropriate analysis of variance test (Steele and Torrie, 1960).

Results and Discussion

Residues in or on forage following field applications of herbicides in pasture or rangeland depend upon the amount of the spray intercepted by the overstory, the rate or mode of application, and the time interval following treatment. Research has shown that initial residues in or on grass from such treatments are not likely to exceed 100 ppm for each pound of herbicide applied (Getzendaner et al., 1969; Morton et al., 1967). Herbicide concentrations in excess of 10^{-4} M in rumen solution would be unlikely following recommended application rates and procedures for 2,4-D and 2,4,5-T. Results of my experiments, conducted to determine the influence of these herbicides on the IVDMD of forage samples (Table 1), indicate 10^{-8} - 10^{-4} M solutions of either herbicide does not significantly alter the digestion activities of the rumen microorganisms when compared with the untreated check. In an attempt to verify the point that the development of the microbial populations was not being altered by these herbicides, dry weights of the treated and untreated rumen liquor, developed in sucrose solutions, were obtained periodically over an 11-day treatment period. Data from this experiment (Table 2) show that the weight increase due to the growth of microorganisms over the 11-day treatment period was not altered by 10^{-4} M solutions of either herbicide. These data indicate that herbicide residues remaining on or in forage samples following spray treatments with 2,4-D or 2,4,5-T apparently will not influence the herbage digestion by ruminants.

Table 1. Influence of 2,4-D and 2,4,5-T concentration (M) on corn and bermudagrass in vitro dry matter digestibility (%).

Herbicide concentration	In vitro dry matter digestibility			
	2,4-D treated		2,4,5-T treated	
	Corn	Bermudagrass	Corn	Bermudagrass
0	48.3[1]	43.0	53.0	42.5
10^{-8}	49.6	42.9	50.4	43.3
10^{-7}	49.8	42.5	50.1	42.6
10^{-6}	50.4	42.7	51.0	43.0
10^{-5}	51.0	43.8	52.3	42.9
10^{-4}	48.8	43.8	53.5	42.9

[1] All means within a column are not significantly different at $P = 0.05$ as tested by analysis of variance test.

Table 2. Influence of 2,4-D and 2,4,5-T on the growth of rumen liquor microbial populations.

Days after treatment	Weight (mg) of dried rumen liquor		
	Herbicide treated		
	2,4-D	2,4,5-T	Check
0	30[1]	31	30
2	33	32	33
4	34	35	34
7	37	38	36
9	38	37	38
11	40	37	38

[1] All means within a horizontal line are not significantly different at $P = 0.05$ as tested by analysis of variance test.

The role of microorganisms in the degradation of the phenoxyacetic acid herbicides is well established (Audus, 1969; Audus, 1951; Kearney and Kaufman, 1969). The majority of this research has been accomplished with soil solutions or microorganisms isolated from soils. Very little research is reported on the degradation of 2,4-D and 2,4,5-T by organisms from sources other than soil. Data from my research (Table 3) indicate that microorganisms in rumen liquor do not degrade 2,4-D or 2,4,5-T over a 10-day incubation period. This was true for samples with and without bermudagrass foliage as an energy source. In vivo methods have indicated that 24 hours following the oral administration of 2,4-D-^{14}C, the majority of the activity had passed through the blood; and by the end of 28 hours post treatment, 90% of the 2,4-D-^{14}C was recovered from sheep urine (Clark et al. 1964). However, previous investigations with microorganisms common in soils have shown that degradation of 2,4-D by microorganisms is preceded by a lag phase lasting up to 6 days during which the herbicide is not appreciably degraded (Smith, 1972; Audus, 1964). This lag phase was followed by a period of rapid substrate disappearance. The lag phase might result from the time required either for development of an effective population of herbicide degrading organisms or time required

Table 3. Influence of rumen microorganisms on the degradation of 2,4-D and 2,4,5-T with and without bermudagrass foliage present.

Days after treatment	Herbicide recovered μg/ml)			
	With bermudagrass		Without bermudagrass	
	2,4-D	2,4,5-T	2,4-D	2,4,5-T
0	22.0[1]	24.2	22.1	24.2
2	22.5	22.9	22.4	23.2
4	21.2	23.9	22.3	23.5
6	19.7	23.3	21.3	23.2
8	19.8	23.8	22.9	23.9
10	20.1	23.6	20.6	23.1

[1] All means within a column are not significantly different at $P = 0.05$ as tested by an analysis of variance test.

for appropriate enzyme induction in a population already present (Kearney and Kaufman, 1969; Akamine, 1951). Results from the in vivo studies did not allow for determining the degradation of 2,4-D or 2,4,5-T following a lag phase of up to 6 days. Data from my experiments indicate that these herbicides are not degraded by microorganisms common to the rumen when incubated for treatment periods as long as 10 days. Therefore, it appears that irrespective of degradation scheme these herbicides are not degraded by the microorganisms common to ruminants under grazing conditions.

Results of the study indicate that: (1) 2,4-D and 2,4,5-T do not alter the rumen microbial functions or development and (2) these herbicides are not readily degraded by rumen microorganisms.

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Calculating Yearlong Carrying Capacity – An Algebraic Approach

JOHN P. WORKMAN AND DONALD W. MacPHERSON

Highlight: *Estimates of yearlong carrying capacity obtained by three different techniques are compared in terms of accuracy as measured by actual carrying capacity of a northern Utah cattle ranch. A new "algebraic" approach appears superior to two established techniques currently in use.*

An important and ever-present problem facing ranchers, public land administrators, and ranch appraisers is balancing forage production with forage use by livestock. Achieving this desired balance is particularly difficult on the seasonal ranges of the Intermountain area where total yearlong carrying capacity is comprised of many diverse sources of livestock feed. Privately owned meadows, U. S. Forest Service mountain summer range, Bureau of Land Management spring and fall foothill range, as well as purchased and home grown hay and concentrates, may all make important contributions to the feed requirements of a single ranch operation. A reliable method of establishing a stocking rate consistent with sustained yield of the forage resource would be welcomed by many practicing range managers.

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Case Study of a Utah Ranch

An actual northern Utah cow-calf operation will be used to compare three methods of balancing forage production and forage utilization. Various feed sources and quantities for the ranch are shown in Table 1.

The ranch currently supports 125 head of breeding cows. One bull is run for each 20 cows (6 bulls), and 20% of the breeding cows are replaced annually with 2-year-old heifers. Thus, 25 heifer calves are kept each year for replacements. Cull cows and 1 bull are sold in July, and at that time replacement heifers and a replacement bull enter the herd. The calf crop percentage averages 85%. Calves are born in March and sold in November at an average weight of 450 pounds. Calves are assumed to exert their initial demands on the forage in July at a weight of about 200 pounds. Using this information and defining 0.1 animal unit months (AUMs) of forage as that required per month by 100 pounds of live animal weight, a stock count chart was calculated (Table 2). The degree of balance between feed availability and feed requirement can be determined by comparing the "total" columns of Table 2. Such a comparison reveals that during all months of the year feed availability is equal to or greater than feed required. Thus, we may conclude that carrying capacity has been correctly estimated by the rancher and the current stocking rate of 125 mother cows is in balance with forage production and the various other sources of feed.

Table 1. Forage balance chart for northern Utah ranch (AUMs).

	Source of feed				
Month	Range	Seeded pasture	Aftermath	Hay	Total available
Jan				160	160
Feb				160	160
Mar				174	174
Apr				174	174
May	100	75			175
June	100	75			175
July	190				190
Aug	190				190
Sept	190				190
Oct	50		150		200
Nov			50	136	186
Dec				160	160
Total					2,134

Three Methods of Estimating Carrying Capacity

Average Month Method

The balanced situation existing on the case study ranch above may well be the result of a series of trial and error adjustments by the rancher. Often, concerns for the protection of the range resource will not allow sufficient time for such an intuitive approach. To provide a means of bringing forage production and forage utilization into balance, it has been common in the past to employ what we will call the "average month" method. This method of estimating yearlong carrying capacity consists of dividing the total annual feed available by 12 in order to calculate the number of AUMs of feed available for the average month:

$$\frac{2134 \text{ AUMs}}{12} = 178 \text{ AUMs}$$

Next, some appropriate rule of thumb is used to calculate the carrying capacity in terms of breeding stock (American Institute of Real Estate Appraisers, 1972); i.e. "on an Intermountain cow-calf operation where calves are dropped in March and 20 percent of the cow herd is replaced annually with home-grown heifers, 1.3 AUMs of feed are required for each breeding cow month." Thus

$$\frac{178 \text{ AUMs}}{1.3 \text{ AUMs/cow}} = \text{137 mother cows capacity}$$

Is 137 head of mother cows a meaningful estimate of yearlong carrying capacity? Obviously 137 head is 12 more cows than the ranch is currently supporting, and the rancher may be holding this amount of unused carrying capacity in reserve for various contingencies. However, to adequately answer this question we must calculate a stock count chart for 137 head (Table 3). Table 3 reflects the same birth dates, bull-cow ratios, replacement ratios, etc. as are currently being practiced for 125 head.

Comparison of total AUMs required for 137 head with total AUMs available in Table 3 reveals that a feed shortage exists for each month of the year, and the annual feed deficit is 175 AUMs. A breeding herd of 137 head is clearly in excess of the carrying capacity of the ranch. The "average method," since it focuses on feed needs of the average month and ignores the requirements of certain limiting months, has yielded an overly optimistic estimate of yearlong carrying capacity.

Limiting Month Method

In an attempt to avoid the high estimate of yearlong carrying capacity given by the "average month" method, we now turn to the "limiting month" approach, which has also been widely used in the past. The limiting months are May and June, when only 175 AUMs of feed are available (Table 1). The months of January, February, March, April, and December have an even smaller feed supply; but during each of these months, purchased

Table 2. Stock count chart for northern Utah ranch (current stocking rate of 125 head).

	Animal class										Total required	Total available[1]
	Bulls (1.5AU)		Cows (1.0AU)		2-year heifers (0.9AU)		Yearling heifers (0.7AU)		Calves (0.325AU)			
Month	Head	AUMs	Head	AUMs	Head	AUMs	Head	AUMs	Head	AUMs	AUMs	AUMs
Jan	6	9	125	125			25	17.5	25	8.1	159.6	160
Feb	6	9	125	125			25	17.5	25	8.1	159.6	160
Mar	6	9	125	125	25	22.5	25	17.5	Born		174.0	174
Apr	6	9	125	125	25	22.5	25	17.5			174.0	174
May	6	9	125	125	25	22.5	25	17.5			174.0	175
June	6	9	125	125	25	22.5	25	17.5			174.0	175
July	6	9	125	125			25	17.5	106	34.5	186.0	190
Aug	6	9	125	125			25	17.5	106	34.5	186.0	190
Sept	6	9	125	125			25	17.5	106	34.5	186.0	190
Oct	6	9	125	125			25	17.5	106	34.5	186.0	200
Nov	6	9	125	125			25	17.5	106	34.5	186.0	186
Dec	6	9	125	125			25	17.5	25	8.1	159.6	160
Total											2,104.8	2,134

[1] From Table 1.

Table 3. Stock count chart for northern Utah ranch (average month method carrying capacity of 137 head).

	Animal class											
	Bulls (1.5AU)		Cows (1.0AU)		2-year heifers (0.9AU)		Yearling heifers (0.7AU)		Calves (0.325AU)		Total required	Total available[1]
Month	Head	AUMs	Head	AUMs	Head	AUMs	Head	AUMs	Head	AUMs	AUMs	AUMs
Jan	7	10.5	137	137			27	18.9	27	8.8	175.2	160
Feb	7	10.5	137	137			27	18.9	27	8.8	175.2	160
Mar	7	10.5	137	137	27	24.3	27	18.9	Born		190.7	174
Apr	7	10.5	137	137	27	24.3	27	18.9			190.7	174
May	7	10.5	137	137	27	24.3	27	18.9			190.7	175
June	7	10.5	137	137	27	24.3	27	18.9			190.7	175
July	7	10.5	137	137			27	18.9	116	37.7	204.1	190
Aug	7	10.5	137	137			27	18.9	116	37.7	204.1	190
Sept	7	10.5	137	137			27	18.9	116	37.7	204.1	190
Oct	7	10.5	137	137			27	18.9	116	37.7	204.1	200
Nov	7	10.5	137	137			27	18.9	116	37.7	204.1	186
Dec	7	10.5	137	137			27	18.9	27	8.8	175.2	160
Total											2,308.9	2,134

[1] From Table 1.

hay or concentrates could be used to offset any deficit. During May and June green forage is available, and cattle normally do not relish hay or concentrates. Thus, during May and June, supplements to forage are not effective, and forage availability during these 2 months limits yearlong carrying capacity.

The "limiting month" approach also employs a rule of thumb concerning monthly feed requirements. If we retain the 1.3 AUMs per breeding cow month used above (American Institute of Real Estate Appraisers, 1972) and apply this requirement to the months of May and June, our calculations are as follows:

$$\frac{175 \text{ AUMs}}{1.3 \text{ AUMs/cow}} = 135 \text{ breeding cows yearlong carrying capacity}$$

The next logical question is whether or not 135 head is a good estimate of the yearlong carrying capacity of the ranch. An accurate answer to this question again depends on the stock count chart showing the monthly AUM requirements for 135 head. Since the feed requirements for 135 head are only slightly less than those of 137 head shown in Table 3, we may conclude that the "limiting month" method has also seriously overestimated carrying capacity of the ranch.

Algebraic Method

The "Algebraic" method which we propose as a solution to the problem of obtaining an accurate estimate of yearlong carrying capacity consists of the following steps: (1) A stock count chart is constructed (Table 4) in which the number of head of each animal class is expressed as a percent of breeding cow carrying capacity (X). Since one bull is required for 20 cows, we list 0.05 X bulls; and since 20% of the breeding herd is replaced annually, we list 0.20 X yearling heifers, etc. Table 4 reflects the calf crop percentage, birth dates, etc., which actually exist for the 125 head of breeding cows currently supported on the ranch. (2) The total AUMs of feed required for each month are calculated in terms of X by summing the requirements for each animal class (for January the total requirement = $.08X + 1.00X + .14X + .07X = 1.29X$). (3) Total breeding cow capacity is calculated for each month by solving the 12 algebraic equations (for January, we solve the equation $1.29X = 160$ for X and obtain 124 breeding cows). (4) The most limiting month is identified

Table 4. Stock count chart employed in algebraic method to determine yearlong carrying capacity.

	Animal class												
	Bulls (1.5AU)		Cows (1.0AU)		2-year heifers (0.9AU)		Yearling heifers (0.7AU)		Calves (0.325AU)		Total required	Total available[1]	Breeding cow capacity
Month	Head	AUMs	Head	AUMs	Head	AUMs	Head	AUMs	Head	AUMs	AUMs	AUMs	Head
Jan	.05X	.08X	X	1.00X			.20X	.14X	.20X	.07X	1.29X	160	124[2]
Feb	.05X	.08X	X	1.00X			.20X	.14X	.20X	.07X	1.29X	160	124
Mar	.05X	.08X	X	1.00X	.20X	.18X	.20X	.14X	Born		1.40X	174	125
Apr	.05X	.08X	X	1.00X	.20X	.18X	.20X	.14X			1.40X	174	125
May	.05X	.08X	X	1.00X	.20X	.18X	.20X	.14X			1.40X	175	125
June	.05X	.08X	X	1.00X	.20X	.18X	.20X	.14X			1.40X	175	125
July	.05X	.08X	X	1.00X			.20X	.14X	.85X	.28X	1.50X	190	125
Aug	.05X	.08X	X	1.00X			.20X	.14X	.85X	.28X	1.50X	190	125
Sept	.05X	.08X	X	1.00X			.20X	.14X	.85X	.28X	1.50X	190	125
Oct	.05X	.08X	X	1.00X			.20X	.14X	.85X	.28X	1.50X	200	133
Nov	.05X	.08X	X	1.00X			.20X	.14X	.85X	.28X	1.50X	186	124
Dec	.05X	.08X	X	1.00X			.20X	.14X	.20X	.07X	1.29X	160	124
Total											16.97X	2,134	125[3]

[1] From Table 1.

[2] For January: $.08X + 1.00X + .14X + .07X = 1.29X$
$1.29X = 160$
$X = 124$ head

[3] Total: $16.97X = 2,134$
$X = 125$ head

and our estimate of yearlong carrying capacity is complete. May and June are again the limiting months for the reasons mentioned above. Thus, our estimate of the yearlong breeding cow carrying capacity of the ranch is 125.

It should be noted that once the limiting feed months (May and June) have been identified, solution of the algebraic equations for these months is sufficient to calculate yearlong carrying capacity. For the purpose of illustration we have included solutions to all 12 equations in Table 4. We have also provided a solution in terms of total *annual* feed requirement and availability which also yields the correct estimate of 125 head: $16.97X = 2134$, $X = 125$.

Since 125 cows are currently being carried (and this number has been adequately supported for the last several years), the 125 cow estimate yielded by the "algebraic" method appears better than those obtained by either the "average" or "limiting" methods. If the rule of thumb for the number of AUMs required per breeding cow month had been set at 1.4 in our example, both the "average" and "limiting" methods would have produced the correct estimate of 125 head. It is the use of the inflexible rule of thumb factor of 1.3 which is responsible for the incorrect estimates of carrying capacity by these two methods. The greater accuracy of the "algebraic" method is due to its ability to compare *month-by-month* estimates of feed requirement with monthly feed availability. Future use of the "algebraic" method will result in more accurate estimates of yearlong carrying capacity and help avoid both over- and understocking of seasonal ranges.

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Calculating Grazing Intensity for Maximum Profit on Ponderosa Pine Range in Northern Arizona

HENRY A. PEARSON

Highlight: *The profit formula is based on forage production, digestibility and utilization, animal weight and daily gain, costs per animal day, and beef prices. Rangeland producing 500–1,000 lb forage per acre would produce maximum profit with moderate utilization.*

Grazing experiments have indicated that, for a few years, heavy grazing gives maximum cattle gains per acre and greatest profits. With prolonged heavy grazing, however, herbage production, beef production, and profits decline. Light grazing usually gives maximum gain per animal but is not often economically feasible. Correct range use most likely lies between maximum gain per animal and maximum short-term return per acre (Stoddart and Smith, 1955).

The objectives of this study were (1) to determine the effects of various grazing intensities on yearling cattle gains, and (2) to determine the grazing intensity which produces maximum profits. This work did not consider the effects on sustained herbage production nor resultant range condition.

Research reported here was conducted when the author was range scientist, Rocky Mountain Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service, at Flagstaff, in cooperation with Northern Arizona University. He currently is principal range scientist, Southern Forest Experiment Station, Pineville, Louisiana. The Rocky Mountain Station's headquarters is maintained at Fort Collins, in cooperation with Colorado State University.

The study area was a ponderosa pine (*Pinus ponderosa* Laws.) range near Flagstaff, Ariz., which was described in detail by Pearson and Jameson (1967). Arizona fescue (*Festuca arizonica* Vasey), mountain muhly (*Muhlenbergia montana* (Nutt.) Hitchc.), bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) J. G. Smith), and sedge (*Carex geophila* Mackenz.) comprised the major portion of the herbaceous vegetation. Forty-five pairs of 9.6-ft^2 plots (one caged, one uncaged) were located in each of seven study pastures for measuring herbage production and percent forage utilization.

Yearling cattle grazed each pasture for a 4-month season, June through September, from 1963 to 1967. Water and salt were manipulated to provide relatively uniform grazing throughout each pasture. The animals were weighed individually at the beginning and end of each grazing season. Forage utilization varied between 5% and 65% through the years due to variations in cattle numbers and forage production. This wide range in forage utilization provided an opportunity to evaluate the effects of different grazing intensities on beef gain per animal and economic returns.

Cattle Gains

Average daily gain per head of yearling cattle was linearly related to percent utilization. The simple regression equation was:

$$g = 1.392 - 0.015U \qquad (1)$$

where U is percent utilization and g is pounds of daily animal gain. Although the coefficient of determination was quite low (0.35), this relationship of cattle gain and grazing intensity is similar to results from studies on crested wheatgrass pastures in northern New Mexico (Springfield, 1963) and on ponderosa pine range in Colorado (Johnson, 1953; Smith, 1967). Adding forage production in a multiple regression analysis of average daily gains nearly doubled the coefficient of determination (0.61) compared to percent utilization alone. The multiple regression equation was:

$$g = 1.198 - 0.186U + 0.00047P \qquad (2)$$

where *P* is pounds of forage produced per acre. Highest gains per animal were obtained on high forage-producing ranges under light grazing. But highest gain per animal does not necessarily mean maximum profits. Cost and return of gains per unit area must also be considered in formulating the most profitable grazing levels.

Economic Implications

Profit maximization involves a comparison of total costs with total receipts at various outputs or grazing levels. To obtain an economic comparison on ponderosa pine range, forage utilization can be analytically evaluated to determine use levels that provide maximum profits. Heavy grazing demands a higher investment than light or moderate grazing, since more animals are required. Although the investment is least with light grazing, the returns are also less than from intermediate or higher levels.

For profit analysis, costs from grazing National Forest or private lands were estimated to be about $0.10 per yearling animal day, and the selling price of beef was determined to be about $0.25 per pound. The cost estimate was based on data which compared public and private costs per animal unit month (Cliff, 1969). Costs from grazing were $4.54 per animal unit month, or $0.15 per animal unit day, or about $0.10 per yearling animal day. Basically profits were equal to the total returns minus the total costs; however, several considerations are used to develop the final profit equation:

$$\text{Profit} = TR - TC \qquad (3)$$

where *TR* is total return per acre and *TC* is total cost per acre;

$$TR = (R)(g)(T) \qquad (4)$$

where *R* is price per lb, *g* is lb gain per day, and *T* is yearling animal days per acre;

$$TC = (C)(T) \qquad (5)$$

where *C* is cost per yearling day;

$$T = \frac{DA}{DD} \qquad (6)$$

where *DA* is digestible forage consumed per acre and *DD* is digestible forage consumed per yearling day. Consequently, these expressions are integrated into the following equation form:

$$\text{Profit} = (R)(g)\frac{DA}{DD} - (C)\frac{DA}{DD} \qquad (7)$$

or

$$\text{Profit} = \frac{DA}{DD}(Rg - C) \qquad (8)$$

or

$$\text{Profit} = \frac{(P \cdot D \cdot U)(0.25g - 0.10)}{0.033w^{3/4}(1 + 0.479g)} \qquad (9)$$

where *P* is forage production in pounds per acre, *D* is percent in vitro forage digestibility, *U* is percent utilization, *g* is pounds of daily animal gain (from equation 2), and *w* is mean animal body weight. The denominator determines *DD*, or the digestible forage consumed per yearling day (Pearson, 1972), while the left portion (*P·D·U*) of the numerator determines *DA*, or the digestible forage consumed per acre. The right portion of the numerator determines the returns and costs per animal day grazed.

To find the percent utilization that produces maximum benefits, set the derivative of the profit equation (equation 9) equal to zero. For example, percent utilization for maximum profit from an Arizona fescue-mountain muhly range producing 500 lb forage per acre with an average 54% digestibility coefficient (Pearson, 1964) and grazed by 500-lb yearling cattle, is calculated as follows:

$$\frac{d}{U}\,\frac{(500)(.54)\,U\,(0.25g - 0.10)}{0.033\,(500)^{3/4}\,(1 + 0.479g)} = 0 \qquad (10)$$

The range is grazed most economically at 30% utilization. Range producing 1,000 lb forage per acre would be grazed most economically at 38%. Both grazing intensities on Arizona fescue-mountain muhly range would be considered moderate, and would not adversely affect long-term forage production, which in most years will exceed 500 lb per acre, air dry under an open forest canopy.

Other variables of concern to the cattle industry are the selling price of beef and cost to graze animals. If the selling price goes up, then the utilization level for maximum profits increases slightly. On the other hand if cattle maintenance costs go up, the utilization level goes down. If both selling price of beef and cost per animal day increase proportionately, then the utilization level for maximum profits remains the same. For example, let's examine and make comparisons for the range producing 500 lb forage per acre. If the selling price of beef was $0.30 instead of $0.25, then maximum profits would be attained at a grazing intensity of 32%. If the costs per animal day were to increase to $0.12, then maximum profits would be attained at the 28% grazing level. If both selling price and cost were increased by 20%, then the grazing level should remain at 30% for maximum profits.

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Cultural, Seasonal, and Site Effects on Pinyon-Juniper Rangeland Plantings

FRED LAVIN, F. B. GOMM, AND T. N. JOHNSEN, JR.

Highlight: *Planting season and cultural treatment effects on emergence and survival of three range species were determined for two cold, dry pinyon-juniper sites in north central Arizona. Plowing was the most effective seedbed preparation for controlling plant competition. Furrow drilling also eliminated a large amount of competition. Emergence and survival (E & S) of Luna pubescent and Nordan crested wheatgrass averaged highest with fall planting, but summer planting was best for E & S of fourwing saltbush. E & S averaged highest on plowed seedbeds and decreased progressively on undercut, undercut-strip, presprayed, sprayed, and control seedbeds. Surface drilling on tilled seedbeds increased E & S over furrow drilling for fourwing saltbush and usually for Nordan crested wheatgrass. Drilling in wide, shallow furrows increased Luna pubescent wheatgrass E & S. Furrow drilling increased E & S for all species on nontilled seedbeds. There were some significant interactions among treatment combinations. Practical application of results is discussed.*

Seeding is often required on pinyon-juniper rangeland to reclaim depleted areas and to balance or increase forage. However, cold, dry sites with spring and fall drought, such as those in central Arizona, are difficult to seed successfully (Gomm and Lavin, 1968).

Under arid rangeland conditions germination, emergence, and establishment are the most critical phases in the growth cycle of seeded plants. Adapted species once established are able to survive conditions that would kill the seedlings. Improving the microenvironment offers a promising potentiality for increasing establishment. Some of the more practical means for bringing about this improvement are planting when growing conditions are most favorable and using seedbed preparation and planting methods that ameliorate soil moisture and temperatures to better suit plant needs (Lavin and Springfield, 1955).

Species requirements and moisture and temperature pattern dictate the best planting time. The larger a seedling becomes before it is subjected to drought, frost, and other adversities, the better chance it has to survive (Plummer et al., 1955). Reynolds et al. (1949) recommended early summer and fall as best time for planting cool season species at the higher elevations in Arizona and New Mexico. Springfield (1956) working in northwestern New Mexico concluded that dependable winter snowfall is needed for fall plantings of pubescent and crested wheatgrass to be consistently successful. Results reported from season of planting trials for fourwing saltbush have been variable, so that all seasons have received favorable recommendation for time to plant (Wilson, 1928; Bridges, 1942; Hervey, 1955; Plummer, Monsen and Christensen, 1966; Springfield, 1970).

Seedbed preparation is usually essential for range seeding success (Pearse, 1952; Plummer et al., 1955; Gomm and Lavin, 1968). The seedbed may vary with the needs of the different species (Waisel, 1962; Pendleton, 1966; Cohen and Tadmor, 1969) but must include control of competing vegetation (Ellern and Tadmor, 1966; Gomm and Lavin, 1968). Seedbeds may be prepared by mechanical or chemical methods (Plummer et al., 1955; Hull et al., 1958). Numerous adaptations have been used, each with its advantages and limitations (Pearse, 1952).

Plowing reduces initial competition to a minimum and is one of the oldest and most widely used of the mechanical methods (Currier, 1971). Undercutting leaves a mulch of vegetative litter on the soil surface, which often improves the microclimate for germination and emergence (Gomm and Lavin, 1968; Tadmor et al., 1968).

Chemical methods involve applying herbicides to unwanted vegetation. These methods create a minimum of soil disturbance and leave a mulch of dead plants on the soil surface (Gomm and Lavin, 1968). They can also be used on areas difficult to prepare by mechanical means. Problems are the planting difficulties engendered by the dead vegetation (Larson et al., 1970; Henry and Johnson, 1971); time and placement requirements of the herbicide used; adverse effects the herbicide may have on the seeded species; and possible herbicide residues.

Two planting methods used in range seeding are surface and furrow drilling. Surface drilling is a preferred method that

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Fig. 1. *Study areas: (*left*) Red Mountain pinyon-juniper savannah showing the dense, even understory of blue grama sod; (*right*) cleared pinyon-juniper woodland at Hart Ranch showing irregular sod cover and shallow, rocky soil.*

provides good control of seed distribution, planting depth, seed coverage and seed-soil contact, allowing a full stand to be obtained with a minimum amount of seed (Lavin and Springfield, 1955; Plummer et al., 1955; Bates and Cox, 1969; Currier, 1971). Furrow drilling increases soil moisture by concentrating precipitation, decreasing runoff, increasing infiltration, and decreasing evaporation (Bertrand, 1965). Furrow drilling alone may eliminate sufficient competition where only remnant cover exists for successful establishment of seeded species (Currier, 1971). Hull et al., (1958) cautions that furrow drilling should be used only in stable soil, so seed will not be buried too deeply by soil sloughing.

Site Description

The study was conducted at two sites: Red Mountain, which is 35 miles northwest, and Hart Ranch, 33 miles southeast of Flagstaff, Ariz. (Fig. 1). Climatic conditions are similar for both sites. Annual precipitation averages between 12 and 14 inches with extremes ranging from less than 6 to over 18 inches. Precipitation is highest during July and August and peaks again in January and February. The driest weather usually occurs from May through June, followed by a less severe dry period from October through November.

Summers are mild with maximum ambient temperatures rarely exceeding 100°F. Winters are cool to cold with temperatures occasionally falling below 0°F. Winter precipitation usually falls as snow that melts quickly and seldom covers the ground for more than a few days at a time.

The elevation above sea level is 6,400 ft at Red Mountain and 6,500 ft at Hart Ranch. The topography at both sites is flat to gently rolling with slopes up to 2%. The Red Mountain site is located on a moderately deep clay loam soil of the Thunderbird Series derived from basaltic material. The Hart Ranch soil is a shallow gravelly loam of the Laporte Series derived from Kaibab limestone. Both are major soil series in the pinyon-juniper woodland of Arizona and New Mexico.

The native vegetation at Red Mountain was pinyon-juniper savannah with a thin stand of medium to small oneseed juniper (*Juniperus monosperma* (Engelm.) Sarg.) and pinyon pine (*Pinus edulis* Engelm.) as the main tree species. The trees were cleared and removed from the experimental area as needed during the progress of the study. The understory consisted predominantly of a dense, uniform blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) sod. At Hart Ranch the original tree stand was denser and larger than at Red Mountain and consisted of a oneseed juniper, Utah juniper (*Juniperus osteosperma* (Torr.) Little) and pinyon pine mixture. This stand had been cabled in 1961. The dead trees on the experimental area were piled with a bulldozer in fall, 1964, and burned in early spring, 1965. Blue grama and broom snake weed (*Gutierrezia sarothrae* (Pursh) Britt. & Rusby) were the main understory species. The blue grama sod was sparser and more broken than at Red Mountain. It also contained fairly large openings where the trees had been piled and burned.

Procedures

Plantings were made at Red Mountain from 1964 through 1966 and at Hart Ranch in 1965 and 1966. A combination split plot-split block design with four replications was used. Split sequence in order of decreasing size was two planting seasons, six seedbed preparations, three species, and two planting methods. Size of the smallest plot was 10 by 18 ft. Data were analyzed by analysis of variance and the Duncan Range Test (Duncan, 1955).

The two planting seasons were summer and fall. Summer plantings were made in late June or early July, with the exception of 1964 at Red Mountain, which was made in early August. Fall plantings were made in early October.

The six seedbed preparations tested were control, prespray, spray, undercut, undercut-strip, and plow. The control received no treatment except for clearing of trees and brush. Prespraying was done one month before seeding with the sodium salt of dalapon[1] in a water carrier. Application was at a rate equivalent to 2 lb active ingredient and at a volume of 20 gal solution/acre. The herbicide solution was applied by boom from a pressure-regulated compressed air sprayer. For the spray method, herbicide was applied immediately before seeding. In all other respects application was the same as for prespraying. Undercutting was done with knife weeder blades attached to an A-frame tool bar. This treatment undercut the native vegetation, mainly blue grama sod, and left it on the soil surface as litter. The undercut-strip method left 8-inch wide strips of live vegetation between 16-inch undercut swaths. Otherwise, procedure was the same as for the undercut method. For summer and fall, 1966, both the undercut and undercut-strip treatments were undercut twice. Plowing was done with a two-bottom moldboard plow to a depth of 4 to 6 inches. After plowing the ground was

[1] Mention of a trademark name or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

Table 1. Live plant cover (%) remaining after seedbed preparation and planting method treatments at Red Mountain.

Seedbed preparation	Planting method: Surface drill	Furrow drill	Mean
Control	22	14	18
Prespray	15	9	12
Spray	19	12	16
Undercut	6	4	5
Undercut-strip	16	9	13
Plow	Trace	0	Trace
Mean	13	8	11

disked, harrowed, and cultipacked producing a fine, firm, smooth seedbed free of plant litter.

Species studied were Luna pubescent wheatgrass (*Agropyron trichophorum* (Link) Rict.), fourwing saltbush (*Atriple canescens* (Pursh) Nutt.) and Nordan crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult.). Seeding rate was 25 viable seed per linear foot of drill row.

Planting methods were surface and furrow drilling. With surface drilling seed was planted ½ to 1 inch deep in rows made with double disk furrow openers. Seeding depth was controlled with depth bands. For furrow drilling, furrows were first formed with hiller disks mounted on a tool-bar assembly. Seed was then drilled into the furrow bottoms in the same manner as for surface drilling. Individual plots had five drill rows starting 1 ft in from the corner on the short axis and spaced on 2-ft centers.

Furrows used in 1964 and in summer of 1965 were 4 inches deep, measured from the original soil surface, and approximately 1 ft wide. A modified furrow was substituted from fall, 1965, through fall, 1966. This furrow was formed with two overlapping hiller disks. It was 2 inches deep from the initial soil surface and approximately 18 inches wide with a broader bottom and more gently sloping sides than the original furrow.

Climatic measurements were made of precipitation by standard rain gauge, air temperature and humidity by hygrothermograph, soil temperature by thermocouple, and soil moisture by gypsum resistance block.[2]

Treatment effects on the existing plant cover were evaluated by ocular estimate and expressed as percentage of total area covered by live vegetation (Brown, 1954). The mean of 12 individual plots was used for each treatment combination. Estimates are for Red Mountain only because the vegetative cover at Hart Ranch was too irregular for meaningful evaluation of treatment effects.

Number of seeded plants per 1000 ft of row length was used to compare treatment effects on seedling emergence and plant establishment. All plants in each plot were counted. Emergence counts were made when seedlings were most numerous and survival counts at the beginning of the second growing season. Since maximum emergence for fall plantings did not occur until the following spring, counts were made during the first and second spring after planting.

Results and Discussion

Elimination of Original Cover

Plowing was the most effective and dependable seedbed treatment tested for eliminating plant competition (Table 1). Undercutting ranked second. Some of the blue grama sod, especially in the undercut-strip seedbeds, died back so slowly after a single undercutting that final plant kill could not be accurately determined in the initial observation. Undercutting the same area twice reduced competing vegetation from 8 to 2% for the undercut treatment and from 19 to 10% for the undercut-strip treatment.

Initial response of blue grama to dalapon prespray and spray treatments was highly variable. Most rapid control was obtained by treatment of actively growing plants. Application often was not made at this time because of our planting schedule. Response of slow-growing and dormant plants to dalapon was delayed. Within a year after treatment, however, control improved and differences among planting seasons and years decreased. Remnant live cover, however, still varied from 1 to 14%.

Bioassays with pubescent wheatgrass and oats were made on soil samples taken from the treated areas 3 to 5 months after spraying. All tests were negative for toxic quantities of dalapon. Thiegs (1955) found that dalapon is broken down in warm moist soil by microbial action in 2 to 4 weeks. Brown and Carvell (1961), however, obtained good control of grasses for 3 years with dalapon.

Surface drilling with double disk openers eliminated very little existing vegetation. Furrow drilling, however, eliminated about one-third of this cover. The deep, narrow furrows appeared to be slightly more effective for vegetation control than the wide, shallow ones.

Emergence and Survival

Planting season and site

Both emergence and survival of Luna pubescent and Nordan crested wheatgrass

Table 2. Plant emergence and survival per 1000 linear ft of row with summer and fall plantings.

Species, site and planting year	Emergence: Summer	Emergence: Fall	Survival: Summer	Survival: Fall
Luna pubescent wheatgrass				
Red Mountain				
1964	20	233*[1]	3	47[2]
1965	2	512*	6	146[2]
1966	1927	888*	213	189
Hart Ranch				
1965	1238	3648**[1]	285	700**
1966	5	282*	2	170**
Mean	638	1113	102	250
Fourwing saltbush				
Red Mountain				
1964	59	1[2]	6	T[3]
1965	30	T*	7	7
1966	930	0	195	27*
Hart Ranch				
1965	552	0[2]	122	0[2]
1966	0	0	0	2
Mean	314	T	66	7
Nordan crested wheatgrass				
Red Mountain				
1965	T	262*	3	32*
1966	477	185	16	40**
Hart Ranch				
1965	191	940*	52	133
1966	0	13**	0	13**
Mean	167	350	18	55

[1] Significant differences between planting seasons are indicated by * at the 5% level and ** at the 1% level.
[2] Analysis of variance not appropriate because plant numbers did not have normal distribution, but differences are obvious.
[3] T = less than one plant per 1000 linear ft of row length.

[2] Lavin, Fred, F. B. Gomm, and T. N. Johnsen, Jr. Some cultural, seasonal, and site effects on soil temperature and moisture for pinyon-juniper rangelands. Unpublished manuscript.

averaged highest from fall plantings (Table 2). Planting year 1966 at Red Mountain was an exception, with summer plantings best. Seedlings from fall plantings did not emerge until the following spring. Springfield (1956) obtained similar results with the same species in northern New Mexico. Frischknecht (1951) reported that fall planting appeared to stimulate growth and development of some cool season grasses and suggested this stimulation might be a contributing factor for increased survival.

Only summer plantings of fourwing saltbush produced adequate emergence and survival. Fall plantings mainly failed, but a few fall-planted seed sometimes emerged during the following summer. At Hart Ranch in 1966, summer as well as fall plantings failed because of the prolonged summer drought. Springfield (1970) found that fourwing saltbush germinated best between 55° and 75°F. Plummer et al., (1966) reported that fourwing saltbush seedlings are highly sensitive to freezing temperatures. Damping off also causes major losses when seedlings emerge during cold wet weather.

Plantings with the best emergence usually had the highest survival. At Red Mountain in 1966, however, summer-planted Nordan crested wheatgrass had the best emergence but the poorest survival because of droughty post-emergence conditions. Survival counts sometimes exceeded those for emergence because of unusually small or grazed seedlings missed in the initial count or because of delayed germination. Cook et al. (1967) found no appreciable number of viable seed remaining after the first growing season for crested and pubescent wheatgrass.

A review of precipitation pattern-planting date relationships indicate their importance to both emergence and survival. In 1964 at Red Mountain the bulk of the rains occurred before and within a week after summer planting and the fall was dry. As a result, stands were poor because the soil was too dry for plant establishment much of the time. In 1965, Red Mountain summer plantings were poor because light showers germinated the seed but did not provide sufficient soil moisture for good establishment during the 15-day dry period that followed. At Hart Ranch the soil remained dry for 2 weeks after summer planting. Then a 1.06-inch rain germinated the seed and five additional well-distributed storms maintained soil moisture above permanent wilting point for a month. This timely moisture resulted in excellent

Table 3. Seedling emergence per 1000 linear ft of row with six seedbed preparation methods.

Species, location and planting year	Control	Prespray	Spray	Undercut	Undercut-strip	Plow	Sig.[1]
Luna pubescent wheatgrass							
Red Mountain							
1964	18b[2]	29b	28b	83b	64b	537a	**
1965	119	284	89	493	306	254	
1966	673d	956cd	1064cd	2305a	1484bc	1962ab	**
Hart Ranch							
1965	1703b	1990b	1940b	2346b	2339b	4340a	**
1966	183	47	70	182	209	167	
Mean	539	661	638	1082	880	1452	
Fourwing saltbush							
Red Mountain							
1964	16	2	32	24	48	57	
1965	1b	0b	2b	6b	0b	82a	**
1966	144c	157c	160c	722b	359bc	1249a	**
Hart Ranch							
1965	98b	47b	338b	266b	65b	842a	*
1966	0	0	0	0	0	0	
Mean	52	41	106	204	94	446	
Nordan crested wheatgrass							
Red Mountain							
1965	106	254	67	146	124	90	
1966	113c	243bc	170c	445ab	357bc	660a	**
Hart Ranch							
1965	312c	663b	414bc	473bc	487bc	1044a	**
1966	9	1	1	4	12	12	
Mean	135	290	163	267	245	452	

[1] Significant differences are indicated by * at the 5% level and ** at the 1% level.
[2] Numbers in each line followed by the same letter are not significantly different.

Table 4. Plant survival per 1000 linear feet of row with six seedbed preparation methods.

Species, location, and planting year	Control	Prespray	Spray	Undercut	Undercut-strip	Plow	Sig.[1]
Luna pubescnet wheatgrass							
Red Mountain							
1964	0[2]	18	5	10	46	72	
1965	5b	88b	6b	178a	65b	116b	*
1966	9b	62b	50b	452a	271a	363a	**
Hart Ranch							
1965	252b	352b	300b	571b	408b	1070a	**
1966	92	52	47	104	133	86	
Mean	72	114	82	263	185	341	
Fourwing saltbush							
Red Mountain							
1964	0b	0b	0b	0b	0b	20a	*
1965	0b	0b	0b	2b	1b	41a	**
1966	1b	19b	20b	142b	46b	440a	**
Hart Ranch							
1965	26b	2b	43b	47b	0b	248a	**
1966	0	2	0	2	0	2	
Mean	5	5	13	39	9	150	
Nordan crested wheatgrass							
Red Mountain							
1965	2b	17ab	9ab	34a	9ab	34a	*
1966	2b	2b	3b	29b	12b	120a	**
Hart Ranch							
1965	6c	113b	47bc	86bc	75bc	226a	**
1966	3	4	4	11	11	7	
Mean	3	34	16	40	27	97	

[1] Significant differences are indicated by * at the 5% level and ** at the 1% level.
[2] Numbers in each line followed by the same letter are not significantly different.

emergence. Many seedlings, however, died during the dry fall. Emergence of 1966 summer plantings at Red Mountain was excellent because of a favorable precipitation pattern and good soil moisture for approximately 4 weeks after seeding. However, a large number of seedlings died during late summer, fall, and spring because of several protracted dry periods. Plantings at Hart Ranch failed because a few light showers germinated the seed but did not provide enough soil moisture for emergence.

Fall planted pubescent and crested wheatgrass appeared to be able to emerge and establish with less moisture than summer plantings. This advantage was probably related to the lower temperatures associated with these plantings.

Overall, precipitation varied between sites and among months and years. Annual precipitation for completely measured years ranged from a high of 15.94 to a low of 7.75 inches with a mean of 10.85 inches. Precipitation averaged higher for Hart Ranch than for Red Mountain. Monthly precipitation ranged from a high of 3.42 to a low of 0.00 inches and over the total measurement period averaged highest for August.

Soil moisture to the 2-inch depth averaged higher for summer than for fall plantings. It also averaged slightly higher for Red Mountain than for Hart Ranch. Soil moisture in relation to treatments applied was somewhat more variable for Hart Ranch than Red Mountain.

Seedbed preparation

Both emergence and survival averaged highest on the plowed seedbed and decreased progressively on the other five seedbeds as follows: undercut > undercut-strip > prespray > spray > control (Tables 3 and 4). For all species, locations, and planting years, considering significant differences only, seedling emergence ranked highest on the plowed or undercut seedbeds and lowest on the control or prespray. Plant survival ranked highest on the plowed or undercut seedbeds and lowest on the control. Species' sensitivity to seedbed preparation appeared to rank as follows: fourwing saltbush > Nordan crested wheatgrass > Luna pubescent wheatgrass. Other research (Lavin and Springfield, 1955; Springfield, 1970) also has shown that seedbed preparation is required for successful range seeding and that seedling establishment usually increases in proportion to the amount of competing vegetation removed.

Variability in emergence and survival on the prespray and spray seedbeds resulted in part from the corresponding variability in initial control of the competing vegetation. Dalapon, even when applied under optimum conditions, usually controlled the blue grama sod too slowly for satisfactory establishment of the seeded species during the same year.

The plowed and undercut seedbeds were the most effective for retaining soil moisture. Inconsistencies obtained, however, suggest that type of seedbed best suited for moisture conservation could differ with precipitation and site characteristics.

Table 5. Plant emergence and survival per 1000 linear feet of row when seeded by surface and furrow drilling.

Species, location, and planting year	Emergence		Survival	
	Surface drill	Furrow drill	Surface drill	Furrow drill
Luna pubescent wheatgrass				
Red Mountain				
1964	187	66	45	5*[1]
1965	157	358	61	92
1966	839	1976**	150	253
Hart Ranch				
1965	2210	2677	373	611
1966	150	137	75	96
Species mean	709	1043	141	211
Fourwing saltbush				
Red Mountain				
1964	53	6*	7	0
1965	29	1*	11	3
1966	491	439	153	69**
Hart Ranch				
1965	424	128	93	29
1966	0	0	1	1
Species mean	199	115	53	20
Nordan crested wheatgrass				
Red Mountain				
1965	129	133	24	11*
1966	345	318	27	29
Hart Ranch				
1965	658	473*	108	77
1966	10	4**	6	7
Species mean	286	232	41	31
Mean	406	480	81	92

[1] Significant differences between planting methods are indicated by * at the 5% level and ** at the 1% level.

Planting methods

Emergence and survival of Luna pubescent wheatgrass averaged highest with surface drilling for 1964 plantings when deep, narrow furrows were used in the alternate treatment. For 1966, however, when wide shallow furrows were used, furrow drilling averaged highest (Table 5). For 1965, emergence and survival averaged highest with surface drilling for summer plantings when deep, narrow furrows were used but was highest for furrow drilling in fall plantings with wide, shallow furrows. In California the best establishment of pubescent wheatgrass was obtained from furrow drilling (Cornelius and Burma, 1970).

Fourwing saltbush emergence and survival averaged best with surface drilling. However, more plants became established in wide, shallow furrows than in deep, narrow ones. Springfield (1970) found that fourwing saltbush emerged best with shallow planting. He was able to establish this species in furrows at one site in New Mexico; but at another, sloughing from the furrow sides caused complete failure.

Nordan crested wheatgrass emergence and survival averaged highest with surface drilling, but results were variable among planting years. Number of emerging and surviving plants were higher with wide, shallow furrows than with deep, narrow furrows. McGinnies (1959) obtained improved establishment of crested wheatgrass in furrows, but Hull (1970) reported equally good establishment of the same species from both surface and furrow drilling.

Soil moisture was consistently higher for furrow than for surface drilling with differences most pronounced where competing vegetation had not been adequately controlled by seedbed preparation. The deep, narrow furrows first used, however, were detrimental to the species planted, because soil sloughing covered the seed too deeply for satisfactory emergence. The wide, shallow furrows were always best for Luna pubescent wheatgrass. Surface drilling was usually best for Nordan crested wheatgrass and always best for fourwing saltbush. Wein and West (1971) concluded that successful seeding in furrows is related to furrow shape, size and spacing, to soil type, and to intensity of precipitation.

Species' response to the planting methods tested are assumed to be related to inherent germination and seedling growth characteristics. Luna pubescent wheatgrass germinates vigorously, and the young seedlings grow rapidly. Thus it could be expected to overcome any adverse effects of moderate silting in wide shallow furrows. Nordan crested wheatgrass germinates well, but initial seedling growth is relatively slow so that both seed and seedlings could be buried too deeply for emergence even in wide, shallow furrows. Fourwing saltbush is sensitive to planting depth and emerges best from shallow plantings. This species, therefore, could be expected to do best with surface drilling.

Interactions

Interaction effects on seedling emergence and plant survival were analyzed between (1) planting season and seedbed preparation, (2) planting season and planting method, (3) seedbed preparation and planting method, and among (4) planting season, seedbed preparation, and planting method. Only significant interactions are discussed unless otherwise designated.

Season-seedbed interactions for emergence of Luna pubescent and Nordan crested wheatgrass were variable among planting years. Plant survival, however, was highest from fall plantings on plowed and undercut seedbeds. Elimination of blue grama competition appeared somewhat more crucial for establishment in summer than in fall plantings. This interaction probably occurred because blue grama grows most rapidly and uses the largest amounts of moisture in July and August. Fourwing saltbush emergence and survival were both highest from summer planting on the plowed seedbed. Treatment combinations which included fall planting mainly failed.

Season-planting method interaction for emergence and survival of Luna pubescent and Nordan crested wheatgrass was inconclusive because of variability among planting years. This variability resulted in part from the two types of furrows used. Fourwing saltbush emergence and survival were consistently highest from surface drilled summer plantings.

Seedbed-planting method interactions for emergence and survival of Luna pubescent wheatgrass were variable among planting seasons and years. For fourwing saltbush, however, emergence and survival were highest from surface drilling on a plowed seedbed. Nordan crested wheatgrass emergence was also highest with surface drilling on a plowed seedbed, but interactions for survival were mainly nonsignificant.

Season-seedbed-planting method interactions for Luna pubescent and Nordan crested wheatgrass were mostly nonsignificant. Overall, however, emergence and survival of Luna pubescent wheatgrass averaged best from fall planting drilled in wide, shallow furrows on a plowed seedbed. For Nordan crested wheatgrass, emergence and survival averaged best from fall planting surface drilled on a plowed seedbed. Fourwing saltbush emergence and survival were significantly best from summer planting surface drilled on a plowed seedbed.

Application

Our results suggest some practical applications for improving establishment of range plantings in the cold, dry pinyon-juniper woodland.

Fourwing saltbush and probably most warm season species need to be planted in summer. Fall is the preferred planting season for cool season species such as the wheatgrasses. They, however, have a wider temperature tolerance than warm weather species and can be planted either in summer or fall.

Plowing is currently the best seedbed preparation for eliminating competing vegetation and establishing seeded stands. Plowed seedbeds, however, were usually invaded by weedy forbs during the growing season following preparation. Gophers also were most numerous on plowed seedbeds, probably attracted by the forb growth. A vesicular crust formed on the surface of the plowed seedbeds at Red Mountain. This structure is common to many soils in arid regions (Springer, 1958).

Effectiveness of undercut seedbed preparation might be improved by using heavier equipment. This equipment should have a rigidly mounted undercutting blade and perhaps vertical fins on the upper surface of the blade to break up the sod.

Dalapon gave consistently good control of blue grama within a year after application. Effectiveness for seedbed preparation might be improved, therefore, by applying it a year ahead of planting.

We had trouble penetrating the soil and covering the seed with a double disk planter on the nontilled seedbeds. Others also have had the same difficulty (Henry and Johnson, 1971). Surface drilling on nontilled seedbeds might be improved by using single-disk openers, improved covering mechanism, and heavier equipment such as the Rangeland drill.

A light layer of native grass mulch over the seed row can improve establishment of seeded species (Springfield, 1970). We observed that the mulch provided by undercutting was pulled away from the seed row by surface drilling and completely removed by furrowing so that mulching benefits were decreased or lost. On the undercut seedbeds some attachment for pulling the mulch back over the seed row after surface drilling might be advantageous.

The advantage of furrow drilling for establishing seeded species is greatest on noncultivated seedbeds where removal of competing vegetation has been inadequate. On cultivated seedbeds, furrow drilling is recommended only for stable soils and for large-seeded species with good seedling vigor. It can be detrimental to small, slow growing seedlings even when soil sloughing from the furrow sides is minimal. Furrow shape is important. It should be wide and shallow with gently sloping sides so that young seedlings are not smothered by excessive soil sloughing.

Seedling size and vigor as well as number are increased by use of favorable seedbed preparation-planting method combinations such as plowing and surface drilling for fourwing saltbush. This increase in size and vigor helps the plants to survive many of the adverse conditions they encounter.

Planted species are damaged by insects, rodents, rabbits, and big game, particularly in the spring. The potential for damage needs to be anticipated and suitable control measures used as necessary.

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Productivity of Tall Wheatgrass and Great Basin Wildrye under Irrigation on a Greasewood-Rabbitbrush Range Site

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Highlight: *Nonbeneficial phreatophytes, greasewood and rubber rabbitbrush, in the Humboldt River Basin annually waste approximately 103,000 acre feet of water that could be used beneficially if forage species were established. After brushbeating, tall wheatgrass and Great Basin wildrye were spring seeded and established by sprinkler irrigation. Irrigation was continued for 3 to 5 years to induce root penetration into a capillary fringe so that grasses would persist as beneficial phreatophytes. After irrigation ceased, productivity of 115 to 710 lb/acre indicated that roots had not reached the capillary fringe and that continued irrigation was necessary to maintain production. Soil physical characteristics restricted root growth, and productivity with limited water or without water was reduced by chemical properties of a saline-sodic soil. Highest production of tall wheatgrass (4000 to 6000 lb/acre) and Great Basin wildrye (2400 to 2600 lb/acre) was obtained 3 years after seeding with weekly irrigations of 1.25 inches.*

About 394,000 acres of greasewood (*Sarcobatus vermiculatus*) and rubber rabbitbrush (*Chrysothamnus nauseosus*) grow in the Humboldt River Basin of northern Nevada. (Nev. Dep. Conser. and Natur. Resources and U. S. Dep. Agr., 1966). These nonbeneficial phreatophytes waste approximately 103,000 acre ft of water yearly. A large portion of this water could be put to beneficial use if phreatophytic vegetation were replaced by plants of higher economic value (Rollins et al., 1968). Dylla and Muckel (1967) speculated that forage species could be established and rooted in the capillary fringe by supplemental irrigation, then grown as phreatophytes without further irrigation. Jensen et al. (1965) reported that one-half to two-thirds as much beef can be produced with well-managed tall wheatgrass on saline-sodic soils as on more desirable land. The objective of this study was to evaluate the longevity and productivity of established stands of seeded species under different irrigation systems.

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Procedures

The study site was in Paradise Valley about 25 miles from Winnemucca in northcentral Nevada. Mean annual precipitation is 8.9 inches. For 7 years water-table depth varied between 5.9 and 9.2 ft and usually dropped about 1.3 ft during the growing season. The capillary fringe wet to about 2.5 ft in the spring. Microrelief was coppice dunes under vegetation surrounded by flat areas of compact barren soils. Coppice sites averaged 33% of the surface. A description of soil chemical and physical properties was presented by Rollins et al. (1968) and Stuart et al. (1971). Cover of native species was 7.1% greasewood, 4.6% rabbitbrush, and 2.7% big sagebrush (*Artemisia tridentata*). Great Basin wildrye (*Elymus cinereus*) and saltgrass (*Distichlis stricta*) occurred in small amounts.

The only method of site preparation was brushbeating. Alkar tall wheatgrass (*Agropyron elongatum*) and Great Basin wildrye were seeded in 12-inch rows at the rate of 2 pls/inch of row in May. Seed was drilled in the surface soil in 1962 and either drilled in the surface soil or in 6-inch deep furrows in 1963 and 1964.

Previous work showed that seedlings could not be established without irrigation. In 1962 and 1963, seedlings were established by one or two sprinkler-applied irrigations/week of approximately 1.25 inches. The following year half the plots received one irrigation/week, while the remainder were not irrigated. Two irrigation treatments were used on the 1964 seeding (Table 1). Water was obtained from shallow ground-water wells (Dylla and Muckel, 1967). Since seedlings established only on dune soil (Rollins et al., 1970), production data were corrected for percent of plot with grass. Three or four replications were used. Production data were analyzed by analysis of variance for a split-plot design, with irrigation treatments the main plots and seedbed and species treatments the subplots. A probability level of 5% was accepted as significant unless otherwise indicated.

Results

Rollins et al. (1968), presented results of the 1962 seeding and reasons for success or failure to establish replacement species on dune and playa soils. The 1963 and 1964 seedings gave similar results, although plant density was lower on the latter. Significantly more seedlings were established with two irrigation/week (19.5 and 11.2 plants/ft of row (pfr) in 1963 and 1964, respectively) than with one/week (15.6 and 8.6 pfr). Density of

Table 1. Irrigation schedule for seedling establishment (1964) and production (1965-1971) of tall wheatgrass and Great Basin wildrye for a 22-week period each year.

	Schedule A				Schedule B			
Year	Frequency	Inches per irrigation	No. of irrigations	Feet applied	Frequency	Inches per irrigation	No. of irrigations	Feet applied
1964	2/week	0.75	44	2.8	Weekly	1.25	22	2.3
1965	Weekly	1.25	22	2.3	Biweekly	2.50	11	2.3
1966	Weekly	1.25	22	2.3	Biweekly	2.50	11	2.3
1967	Weekly	1.50	22	2.8	Biweekly	3.00	11	2.8
1968	Biweekly	3.00	11	2.8	Monthly	3.60	6	1.8
1969	None	0.00	0	0.0	None	0.00	0	0.0
1970	None	0.00	0	0.0	None	0.00	0	0.0
1971	None	0.00	0	0.0	None	0.00	0	0.0
Total				13.0				11.5

wheatgrass was higher (17.6 and 9.9 pfr) than for wildrye (11.7 and 7.4 pfr). Seedbed treatments were significantly different only in 1964 when density in furrows (10.1 pfr) was greater than in the drill treatment (7.2 pfr). These results showed that even the poorer irrigation, seedbed, and species treatments produced excellent seedling stands on dune soils. Stands were not established on playa soil.

Yield response on the 1962 and 1963 seedings was evaluated for 3 years. On both seedings, one irrigation/week produced more herbage (1002 lb/acre) than did no irrigation (179 lb/acre). Wheatgrass and wildrye produced similarly in all years after the 1962 seeding. On the 1963 seeding, wheatgrass (821 lb/acre) produced significantly more than did wildrye (268 lb/acre). Maximum production of both species declined rapidly without irrigation. For example, yield the first year without irrigation ranged from 56 to 96% of that with one irrigation/week. Yield the second year ranged from 14 to 24%, and in the third year from 0 to 3% of that with irrigation.

Such a rapid decline in yield and low yield indicated that established grasses were not partial phreatophytes and that some irrigation was necessary to maintain productivity and perhaps to stimulate root growth into the capillary fringe. Production data (Table 2) for extended irrigation treatments on the 1964 seeding are discussed by year-periods: 1965-1967; 1968; and 1969-71.

1965-67

Although excellent stands were obtained with both irrigation treatments in 1964, yearly production in 1965, 1966, and 1967 was significantly greater with weekly irrigation. Wheatgrass produced more than did wildrye in each year. Yield did not vary with seedbed treatment except in 1967 when more herbage was produced in furrows. Highest production was from wheatgrass in furrows in 1967. Production was least in 1965, higher in 1966, and greatest in 1967.

1968

Less frequent irrigation in 1968 resulted in significantly less yield than in any previous year. Production was greater with two irrigations/month than with monthly irrigation. Wheatgrass produced more than did wildrye. A significant (0.10) irrigation x seedbed interaction indicated that with less water, production was maintained at a higher level in the furrows than in the drill treatment. In fact, production in furrows was greater than in any year except 1967.

1969-1971

A year after all irrigation had ceased, total production was significantly less than in the preceding year. Wheatgrass produced more than wildrye in 1969, but the two species were similar in 1970 and 1971. Production was greater in furrows in 1969, but did not vary with seedbed treatment in 1970 and 1971. For 1 year after irrigation ceased, higher productivity was maintained in furrows than in the drill treatment. In 1971, no treatment or interaction significantly affected yield. By 1970 and 1971 productivity had reached equilibrium with the existing site factors and yield was significantly lower than in any other year. Although grass production varied between 134 and 710 lb/acre in 1970 and between 115 and 595 lb/acre in 1971, plant vigor was poor. Many dead portions of bunches were evident and reproductive culms were absent on plants in solid rows. Average leaf length of wheatgrass and wildrye was 10 and 12 inches, respectively. These plants did not appear capable of withstanding grazing pressure.

Results indicate that even after supplemental irrigation for 5 years, roots had not reached the capillary fringe. This conclusion is supported by comparative yield of tall wheatgrass (2940 lb/acre) grown in lysimeters with a water table in the root zone (Dylla et al., 1972).

Discussion and Conclusion

Irrigation was required to establish potentially productive stands of tall wheatgrass and Great Basin wildrye. Excellent production was obtained after 2 to 3 years with weekly irrigations of approximately 1.25 inches of water. With irrigation, wheatgrass was more productive than wildrye. High production was not maintained without irrigation although production with limited water was greater in furrows. Use of furrows was not necessary for establishment, and a furrow effect could not be maintained under grazing or haying without periodic land treatment. Varying degrees of productivity were maintained for 1 year after cessation or irrigation, perhaps because some water from the previous year's irrigation was stored in the soil profile.

Robertson (1955), found roots of tall wheatgrass to depths of 11 ft in irrigated saline-alkali soils. Therefore, in the present study, why was a productive stand not obtained without irrigation when the capillary fringe was at 2.5 ft at the beginning of the growing season and dropped to only 3.8 ft during the growing season? Soil morphology and chemistry provide the best answers. Stuart et al.

Table 2. Production (lb/acre) of two species for 7 years in response to irrigation and seedbed treatments. Seeding was made in May, 1964.

Irrigation schedule	Species	Seedbed	Production						
			1965	1966	1967	1968	1969	1970	1971
A	Tall wheatgrass	Drill	1138	2669	4224	2726	1517	461	595
		Furrow	1050	3091	6163	2534	1382	134	480
	Basin wildrye	Drill	654	2227	2611	1939	442	710	365
		Furrow	530	1613	2419	1632	864	384	346
B	Tall wheatgrass	Drill	694	1651	1651	1709	614	230	346
		Furrow	727	2208	5434	3994	2189	403	499
	Basin wildrye	Drill	115	192	499	134	154	154	115
		Furrow	134	576	1081	1344	806	691	441

(1971), found horizons very strongly cemented by calcium or silica at depths of 1.6 to 2.8 ft. Grass roots were abundant above these horizons. Only a few roots were found in the strongly cemented plates with only an occasional root below. Obviously, this horizon limited root penetration to the capillary fringe, and water in the fringe was unavailable to seeded grasses for most of the growing season. Without irrigation, this site had the productive capacity of a dryland environment. This dryland environment perhaps was aggravated by the saline-sodic soil. Soil chemistry of dune soils to the 3.5 ft depth showed: pH range of 8 to 10; conductivity range of 5 to 20 mmhos/cm; exchangeable sodium range of 27 to 75%; and boron range of 5 to 18 ppm. Under these conditions of restricted rooting depth and saline-sodic soils, soil moisture tension, osmotic pressure of the soil solution, and possible specific-ion effect from sodium and boron may be responsible for reduced yield without irrigation.

Significant yield differences from irrigation treatments in 1965, 1966, and 1967 were obtained with approximately the same amount of water (Table 1). Jensen et al. (1965) reported that stand establishment in saline-sodic soils was enhanced by more frequent irrigation because more moisture remained in the surface soil prior to the next irrigation. This same relationship may be important in stand productivity since more water in the root zone would lower moisture tension, dilute and leach salts[1], and reduce pH and sodium.

The amount of water that can be applied to maintain production depends on groundwater availability and pumping costs. Dylla and Muckel (1967) estimated that the cost of water pumped by gasoline engine at a rate of 30 gpm for a 1920 hr/season from a shallow aquifer (21 ft) was $18.61/acre ft. Water cost for the one irrigation/week treatment would be $42.80 for 1965 and 1966, and $52.11 for 1967. The highest water-use efficiency was obtained in 1967 with one irrigation/week and was 153 and 95 lb hay/acre inch of water, respectively, for tall wheatgrass and Great Basin wildrye.

Areas selected for treatment should have a large portion of the microrelief with soil of chemical and physical characteristics suitable for this kind of revegetation program. In practice, brush could be killed with herbicides and the area seeded the following spring with a rangeland drill.

[1]Unpublished data, Darrell M. Stuart, Agricultural Research Service, Soil and Water Conservation Research Branch, U.S. Dep. Agr., University of Nevada, Reno.

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Seasonal Changes in Quality of Some Important Range Grasses

L. D. KAMSTRA

Highlight: *Holocellulose, hemicellulose, and in vitro fiber digestibility were significantly different between cool and warm season grasses. A significant class x date interaction for protein and lignin suggested that each forage could be expected to follow a different growth pattern during the growing season. Sugars (xylose, arabinose, galactose, and glucose) were found as hemicellulose components in all grasses at all cutting dates. Xylose was the most prominent structural sugar in all grasses studied. In vitro dry matter digestibility could be most easily adapted to routine studies of forages, but cannot be expected to define the contributions of individual parameters making up plant dry matter.*

The nutritive differences among grasses at various sampling dates suggest the value of a mixture of desirable grasses. This would assure grazing animals continued nutrition throughout the grazing period.

A critical examination of the nutritive potential of native grasses should assist in decisions relative to any planned changes in range ecosystems. Such alterations might stem from continued economic pressures to elevate the productivity of rangeland by fertilization, interseeding with introduced species, or replacement by various crops.

Studies of the energy-containing components of plants has long been neglected because investigation of these complex components is difficult. The main difficulty was the failure to isolate discrete carbohydrate fractions free from lignin encrustation. Isolation of relatively lignin-free holocellulose, which contains the major portion of plant carbohydrates, has aided plant carbohydrate research (Schmidt et al., 1931; Wise et al., 1946; Ely and Moore, 1955a; Kamstra and Thurston, 1965). This study is a consideration of in vitro dry matter digestibility, crude protein, and holocellulose carbohydrate components of selected prairie grasses during a growing season. Species selected are important in the mixed prairie of western South Dakota.

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Methods

Two replicates of western wheatgrass (*Agropyron smithii*) and green needlegrass (*Stipa viridula*), cool season species, and blue grama (*Bouteloua gracilis*) and little bluestem (*Andropogon scoparius*), warm season species, were collected June 11, June 22, July 11, and August 11. An additional collection of warm season grasses was made September 28. The phenology of the various grasses at each cutting date is indicated in Table 1. Samples were hand-clipped approximately 5 cm above ground level from pastures in good range condition deferred for winter grazing. All samples were air-dried at 65° C, ground to 40 mesh, and stored at −20° C.

The sampling areas were located at the Cottonwood Range Field Station 120 kilometers east of Rapid City. This area has average annual rainfall of 38.35 cm. The total annual rainfall for 1967 was 12.7 cm above normal with the greatest precipitation occurring in June followed by near drought conditions in July and August. Soils are formed mainly from Pierre shale. Although the sampling area included clayey, shallow, and overflow soil groups, sampling sites were located in the clayey soil groups. The soil was weakly developed in the sampling sites for blue grama and little bluestem but would be classed as thin clayey.

Carbohydrates were studied by initial preparation of the holocellulose fraction (Whistler et al., 1948) with further separation and identification of the neutral sugar components of hemicellulose (Myrhe and Smith, 1960). Cellulose was prepared as an isolate from holocellulose from a separate plant sample (Crampton and Maynard, 1938), as well as by the detergent method of Van Soest (1963) to obtain a fiber fraction. Crude protein was determined on all samples by the A.O.A.C. method (1960). In vitro dry matter digestions (IVDMD) by the Tilley and Terry (1963) procedure was used to estimate animal utilization.

Table 1. Phenology of prairie grasses at each sampling date.

Grass species	Stage of maturity				
	June 11	June 22	July 11	August 11	September 28
Western wheatgrass	Vegetative	Early flowering	Full flowering	Shattered	
Green needlegrass	Late vegetative	Full flowering	Seed ripe	Shattered	
Blue grama	Early vegetative	Vegetative	Vegetative	Some seedstalks	Several seedstalks
Little bluestem	Early vegetative	Vegetative	Vegetative	Late boot	Seed ripe

Results and Discussion

Fibrous Fractions and Lignification

Fibrous fractions of plants usually increase with maturity (Kamstra et al., 1968). This trend was apparent with all grasses except blue grama, which made little growth until late season rains in August and September. Detergent cellulose analysis showed that little bluestem was the most fibrous (51%) and western wheatgrass the least (38%) by the end of the growing season (Fig. 1). Similar patterns were indicated by cellulose isolated by the Crampton and Maynard method (1938) and by cellulose isolated from the holocellulose fraction. Hemicellulose, on the other hand, increased during June and decreased or remained stable during July and August. Western wheatgrass and green needlegrass had the highest hemicellulose values throughout the season and had very similar amounts at each collection date. The high hemicellulose content of these grasses should contribute to better animal utilization, since hemicellulose was shown to be of much higher digestibility than the cellulose component of the holocellulose fraction (Kamstra and Thurston, 1965).

Lignification in all species increased continually throughout the growing season. As the lignin content of a forage increases, digestibility invariably decreases, although the most highly lignified forage is not always the least digestible (Kamstra et al., 1958) since so many factors contribute to digestibility. All factors considered, however, lignin is one of the more important single plant components that determine the digestibility of plant fibers. Green needlegrass and little bluestem were the most highly lignified at the end of the growing season, while blue grama and western wheatgrass had the lowest lignin content. Cool and warm season grasses lignify in a manner somewhat unique to their group, that is, lignification patterns are similar for species within each group. A significant ($P<0.05$) class x date interaction suggests that the grasses did not lignify similarly with date.

Crude Protein and In Vitro Digestibility

Crude protein content of all species decreased significantly with maturity (Fig. 2). A significant ($P<0.05$) class x date interaction was also shown for crude protein. The wide variation in protein content of blue grama at different collection dates would contribute to this interaction.

The 48-hour in vitro digestibility of dry matter and cellulose were used to predict animal utilization. Significant differences ($P<0.05$ and $P<0.01$, respectively) in dry matter and cellulose digestibility existed between cool and warm season grasses. The digestibility of the cellulose portion of the cool season grasses remained at a higher level than that of warm season grasses throughout sample collection period. Digestibility of warm season grasses increased following a 4.4 cm rainfall about 2 weeks prior to the September 28 collection (Fig. 3).

Neutral Sugar Components of Hemicellulose

The neutral sugar components of hemicellulose were xylose, arabinose, galactose, and glucose in order of decreasing concentration. This was observed for all grasses collected at all dates (Table 2). Although not included in this study, it was interesting to note that the rhizomes of western wheatgrass had much higher levels xylose with lesser amounts of galactose

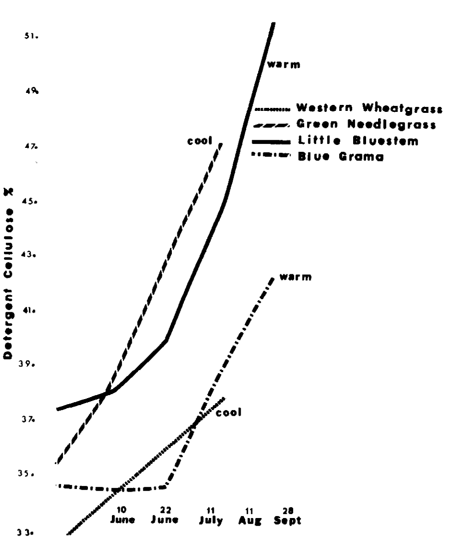

Fig. 1. *Relation of grass species and sample date to cellulose content.*

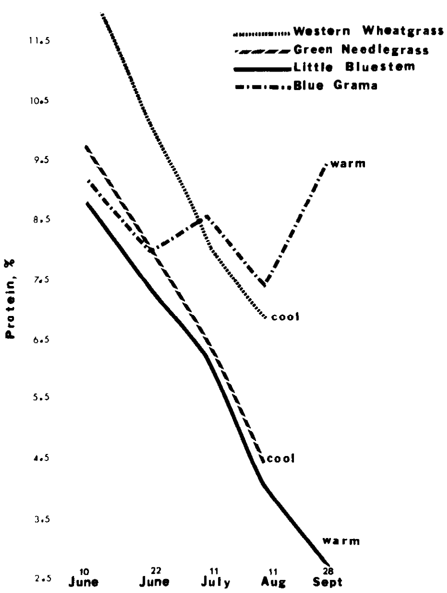

Fig. 2. *Relation of grass species and sample date to protein content.*

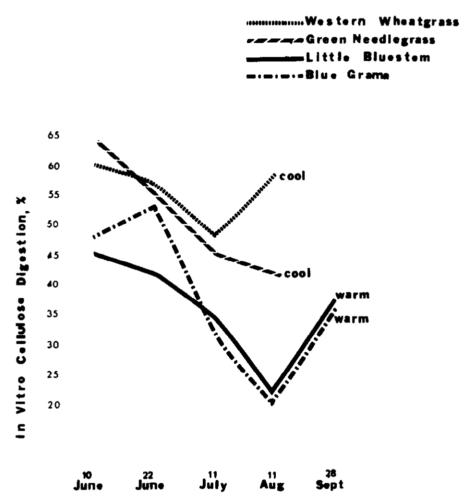

Fig. 3. *Relation of grass species and sample date to in vitro cellulose digestibility.*

Table 2. Comparative neutral sugar components of prairie grasses at various cutting dates.

Grass species	Collection date	Percent of hemicellulose hydrolzate			
		Xylose	Arabinose	Galactose	Glucose
Western wheatgrass	June 10	31.8	30.4	22.0	15.8
	June 22	32.8	31.0	20.9	15.2
	July 11	39.3	33.1	17.0	10.7
	Aug. 11	41.4	32.4	14.7	11.5
Green needlegrass	June 10	33.5	32.1	21.7	12.7
	June 22	33.9	31.9	21.9	12.4
	July 11	32.1	30.6	21.4	15.9
	Aug. 11	37.0	29.6	20.3	13.1
Little bluestem	June 10	32.5	31.3	25.8	10.4
	June 22	30.1	28.7	27.8	13.4
	July 11	33.2	28.9	24.7	13.2
	Aug. 11	35.6	34.5	22.6	7.4
	Sept. 28	38.7	31.9	19.1	10.2
Blue grama	June 10	29.1	28.4	24.5	18.0
	June 22	32.0	29.2	24.1	14.8
	July 11	34.9	27.4	21.1	16.6
	Aug. 11	30.4	29.2	23.1	17.3
	Sept. 28	30.8	28.5	22.9	17.7

and glucose. The high comparative levels of xylose and arabinose suggest that these sugars are the major structural units of hemicellulose (Myhre and Smith, 1960, and Kamstra et al., 1968). The same hemicellulose components were found in subtropical grasses (Kamstra et al., 1966) and with a different series of cool and warm season grasses collected at the Antelope Range Field Station (Cogswell, 1971). The relationship of the relative concentration of any one neutral sugar component of hemicellulose to forage quality has not been established. As noted previously, the total amount of hemicellulose, however, appears to enhance digestibility (Kamstra et al., 1965).

It would be difficult to envision a selection of cultivated grasses which would provide the flexibility to withstand extreme weather variations and grazing pressures offered by mixed prairie grasses. As this study indicates, each grass has its own seasonal growth characteristics that can vary its nutritional value as maturation proceeds. Direct comparison of quality components between cultivated and range grasses at equivalent maturity stages cannot be made accurately since the usual definitions do not consistently apply to range grasses. Many range grasses, for example, produce seed only during favorable years. This is especially true of grasses such as western wheatgrass, which does not depend on seed for reproduction. It would appear that introduced grasses should be selected on noncomparative basis to serve a specific need such as increase forage production or to provide additional nutritional benefits. The rapid decrease in protein and increase in lignification of cool and warm season grasses as the growing season progresses are accepted negative quality indices to animal utilization of forage. As more intense management becomes possible for large prairie acreages, this problem should receive consideration. Introduction of legume forages could alleviate protein shortages, which are chronic to late season grazing. Fertilization practices could be used as a tool to promote growth of desired range species for grazing during selected periods of the growing season. Grazing or clipping of forages have been shown to increase digestibility (Kamstra et al., 1966, and Kamstra et al., 1968) and with proper management could provide better utilization. Above all, however, a thorough understanding of nutritional qualities of the various range grass species should precede altering competition among range grasses as it now exists.

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Nutritive Value of Hay from Nitrogen-Fertilized Blue Grama Rangeland

R. J. KELSEY, A. B. NELSON, G. S. SMITH, AND R. D. PIEPER

Highlight: *Wether lambs were used in a feeding study (voluntary consumption, nutrient digestibility, metabolizable energy, and nitrogen retention) to evaluate the nutritive value of hays harvested from unfertilized and nitrogen-fertilized blue grama rangeland. Fertilization increased consumption by 29%; increased digestibility of dry matter, protein, and energy by about 5%; and increased the retention of nitrogen by about 7%, although the percentage retention of absorbed nitrogen (biological value) was apparently depressed.*

Increasing the productivity of native rangelands has received considerable attention within the past few years, and it has been demonstrated that nitrogen fertilization of native blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.) rangeland may increase forage production several fold (Reed, 1965; Banner, 1969, Schickedanz, 1970). However, information is lacking concerning the effect of nitrogen fertilization on forage consumption, digestibility of nutrients, and nitrogen retention by animals consuming nitrogen-fertilized rangeland forage. Observations of these functions presented herein were reported in a preliminary communication (Kelsey et al., 1971).

Procedures

Forage was harvested as hay from nitrogen-fertilized and unfertilized (control) plots of native rangeland located at the Fort Stanton Cooperative Range Research Station in the foothills of the Sacramento Mountains of Southern Lincoln County, N.M., at elevations ranging from 6,200 to 7,000 ft. Average annual rainfall for the area is about 15.3 inches. The fertilized plot received 40 lb of nitrogen per acre in the form of urea (45% nitrogen), applied aerially in June, 1969. The forage was harvested from treated and untreated plots in August, 1969, when blue grama was in the full-bloom stage and stored in burlap bags until used in the animal feeding study (about 3 months). Additional hay was harvested from the treated and untreated plots in September of 1969 when blue grama was in the mature stage, and this supply was used as the hay with which the animals were adjusted to their respective diets during the feeding trial. The hay was composed mainly of blue grama (about 70%) and various other grasses and forb species, as described by Schickedanz (1970).

Four crossbred wether lambs from the New Mexico State University College Farm flock were used to evaluate nutritive value of the hays from treated and control plots. The lambs were uniform in size and condition, and averaged about 80 lb in body weight during the study. A "crossover" design was used in the feeding trial: two lambs were randomly assigned to each of the two hay sources during an initial feeding trial; afterwards the two treatments were reversed with the same lambs being fed. Within each of the two feeding periods, there was a 10-day adjustment period, followed by a 14-day preliminary period with measurement of *ad libitum* feed intake, and finally a 10-day period of equalized intake which was regulated at approximately 90% of the *ad libitum* intake. The lambs were fitted with canvas fecal collection bags and maintained in metabolism stalls throughout the study. During the last 5 days of the period involving equalized feed intake, feces and urine were collected and sampled for analysis, along with representative samples of the hays consumed.

Fecal samples collected were 10% of the total daily excretion; urine samples were obtained by diluting the daily excretion to 2 liters and taking 50-ml aliquots for the composite sample for each lamb.

Samples of hays, orts (refused feed), and feces were analyzed by methods of the A.O.A.C. (1965) for dry matter, organic matter and ash, nitrogen, ether extract, and crude fiber. Likewise, nitrogen content of urine samples was determined by the method of the A.O.A.C. (1965). Samples of hays, orts, and feces were analyzed for acid-detergent fiber (ADF) and acid-detergent lignin (ADL) by the method of Van Soest (1963), and for cell-wall constituents (CWC) by the method of Van Soest and Wine (1967). Samples of hay, feces, orts, and urine were analyzed for gross energy (heat of combustion) in a Parr oxygen bomb calorimeter (Parr Instrument Co., 1960). Urine samples were absorbed on filter paper to facilitate ignition. Samples of hays, orts, and feces were dried to constant weight at 65°C and ground in a Wiley mill to pass a 40-mesh screen in preparation for analyses.

Digestion coefficients were calculated after corrections were made for feed refusals and sorting effects associated with the orts. The value reported by Harris and Mitchell (1941) was used to calculate metabolic fecal nitrogen (i.e., 0.55 grams m.f.n. per 100 g dry matter intake), and the value reported by McLaren et al. (1959) was used to calculate endogenous urinary nitrogen (i.e., 33 mg e.u.n. per kilogram of body weight). The formula of Swift et al. (1948) was used to estimate methane production. Analysis of variance was performed on the data as described by Steel and Torrie (1960).

Results and Discussion

The chemical composition of hays obtained from nitrogen-fertilized and unfertilized blue grama rangelands is shown in Table 1. The nitrogen-fertilized hay

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Table 1. Average chemical composition and gross energy of unfertilized and nitrogen-fertilized blue grama hay.

Chemical composition	Treatment[a] Unfertilized	Fertilized
Dry matter (%)	96.2	95.8
Composition of dry matter (%)		
Organic matter	92.8	93.5
Crude protein (N X 6.25)	7.0	8.8
Ether extract	1.7	1.7
Cell wall constituent	76.1	73.9
Crude fiber	35.2	35.6
Acid-detergent fiber	46.3	42.7
Acid-detergent lignin	6.3	6.4
Nitrogen-free extract	48.8	47.4
Gross energy (kcal/g)	4.2	4.2

[a]Each value represents the mean for at least three measurements (on three sub-samples) on a single, representative sample for each hay. The statistical significance of differences between means for the various components was not tested.

Table 2. Dry matter intake, apparent digestion coefficients, and TDN intake for unfertilized and nitrogen-fertilized blue grama hay.

Item	Treatment Unfert.	Fert.	Diff.	C.V.[a]
Dry matter intake (g/day)	521.0	673.0	152.0**	7.0
Dry matter (%)	48.2	54.2	6.0*	4.7
Organic matter (%)	51.3	57.0	4.7*	4.3
Crude protein (%)	41.0	52.6	11.6**	0.8
Ether extract (%)	20.3	20.6	0.3	26.4
Cell wall constituents (%)	54.5	59.3	4.8	4.3
Crude fiber (%)	54.4	61.4	7.0*	4.2
Acid-detergent fiber (%)	49.9	53.3	3.4	5.3
Acid-detergent lignin (%)	5.2	17.7	12.5*	47.1
Nitrogen-free extract (%)	51.6	55.7	4.1	5.3
Total digestible nutrients (%)[b]	48.1	53.6	5.5*	5.1
TDN intake (g/day)	251.0	361.0	110.0**	10.6

[a] C.V. = Coefficient of variation (%).
[b] Total digestible nutrients expressed as a percent of dry matter.
* $P<0.05$.
** $P<0.01$.

was higher in crude protein content, and this reflects a lower content of nitrogen-free extract (NFE) when compared to the unfertilized hay. Contents of cell-wall constituents and acid-detergent fiber were higher in the unfertilized hay. A summary of data showing dry matter intakes, apparent digestion coefficients, and total digestible nutrient (TDN) values is presented in Table 2.

The lambs consumed 152 g per day more of the fertilized hay than the unfertilized hay, which amounted to 129% of the intake for unfertilized hay ($P<0.01$). In an extensive review of factors that influence intake of forage, Marten (1969) has cited numerous reports of increased forage intake due to nitrogen fertilization.

Nitrogen fertilization increased ($P<0.05$) the digestibility of dry matter, crude protein, crude fiber, and even acid-detergent lignin, thereby increasing the total digestible nutrients (TDN) of the fertilized hay. Similar findings with cool season grasses have been reported by Markley et al. (1959) and Merrill et al. (1961). Although the apparent digestibility of lignin (ADL) was increased, the coefficient of variation for ADL is notably larger than coefficients of variation for other components. There were slight differences in digestibility coefficients for cell-wall constituents, acid-detergent fiber, and nitrogen-free extract in favor of the fertilized hay; but these differences were not significant ($P<0.05$).

The intake of TDN (Table 2) associated with the fertilized hay was 144% of the value for unfertilized hay ($P<0.01$), a difference which reflects not only a greater digestibility of nutrients but also a greater intake.

Values for digestible energy and metabolizable energy are shown in Table 3. Both digestible energy and metabolizable energy were increased as a result of nitrogen fertilization ($P<0.10$).

Nitrogen balance data are summarized in Table 4. Fertilization increased values for nitrogen intake, fecal nitrogen, apparent nitrogen digestibility, metabolic fecal nitrogen, nitrogen absorption, true digestibility of nitrogen, urinary nitrogen, and nitrogen retention. The increase in true digestibility of nitrogen due to fertilization (1.8%), though significant ($P<0.01$), is considerably less than the difference in apparent digestibility (11.9%), an observation which indicates the importance of the correction for metabolic fecal nitrogen in such studies where differences in intake occur.

Although the biological value of nitrogen (Table 4) is significantly greater ($P<0.01$) for unfertilized hay, the difference is due, in part at least, to difference in nitrogen intake (Forbes et al., 1958) as well as possible differences in

Table 3. Digestible and metabolizable energy as affected by unfertilized and nitrogen-fertilized blue grama hay.

Item	Unfert.	Fert.	Diff.	C.V.[a]
Gross energy digested (%)	46.5	51.3	4.8	5.3
Digestible energy, (kcal/g)	2.0	2.1	0.1	5.0
Digestible energy intake, (kcal/day)	1023.0	1439.0	416.0*	11.2
Gross energy metabolized (%)	38.6	43.2	4.6	6.6
Metabolizable energy,(kcal/g)	1.6	1.8	0.2	7.2
Metabolizable energy intake, (kcal/day)	849.0	1211.0	362.0*	11.8

[a]C.V. = Coefficient of variation (%).
*$P < 0.05$.

Table 4. Nitrogen metabolism in lambs fed unfertilized and fertilized blue grama hay.

Determination	Unfert.	Fert.	Diff.	C.V.[a]
Nitrogen intake (g/day)	5.9	9.5	3.6**	5.5
Fecal nitrogen (g/day)	3.5	4.5	1.0**	5.8
Apparent nitrogen digestibility (%)	40.7	52.6	11.9**	0.7
Metabolic fecal nitrogen (g/day)	2.9	3.7	0.8**	7.0
Nitrogen absorption (g/day)	5.3	8.7	3.4**	5.6
True nitrogen digestibility (%)	89.8	91.6	1.8**	0.3
Urinary nitrogen (g/day)	2.4	4.3	1.9**	3.4
Nitrogen retention (g/day)	0.0	0.7	0.7*	77.8
Nitrogen intake retained (%)	0.0	7.4	7.4	171.9
Endogenous urinary nitrogen (g/day)	1.2	1.2	0.0	4.2
Nitrogen utilized (g/day)	4.1	5.6	1.5*	9.1
Biological value (%)	77.4	64.4	– 13.0**	4.5

[a] C.V. = coefficient of variation (%).
* $P < 0.05$.
**$P < 0.01$.

the actual nutritive value of the nitrogenous components of the hays. The fertilized hay is actually the more nutritious.

The increases in nutritive value of blue grama rangeland forage due to fertilization, together with increased yields (Banner, 1969; Schickedanz, 1970), suggest that fertilization of this type of rangeland promises economic returns of considerable magnitude to many areas of the western United States.

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Nitrogen and Paraquat Saves Range Forage for Fall Grazing

FORREST A. SNEVA

Highlight: *Chemical curing of N-fertilized crested wheatgrass was examined in 3 years. Both N and paraquat, singly and in combination, significantly influenced various stand components. The combined treatments increased fall herbage yield 40%, crude protein concentration 68%, and crude protein yield 148% above that of the control.*

Low gain of animals grazing poor quality forage on late summer-early fall ranges is a major problem on most semiarid rangelands. Sneva et al. (1972) have shown that yearling cattle gained 0.6 lb more per day when grazing chemically cured crested wheatgrass (*Agropyron desertorum*) than yearling grazing naturally cured grass. Chemical curing of seeded ranges appears to have promise, but greater return could be realized if the production base could be increased.

Greatest return from nitrogen (N) fertilization of seeded stands occurs in the more favorable moisture years and when grasses are permitted to reach maturity (Sneva, 1972), but the combination of N fertilizer and favorable moisture produce a low quality mature forage. Rarely is more low quality forage needed to balance the annual forage supply.

Greatest return from chemical curing should result when grasses are cured at a hay stage of maturity that maximizes total digestible nutrient production. This has generally been shown to occur prior to peak yield and in grasses is characterized by the early flower stage. Thus, chemical curing applied at that time would be expected to result in reduced herbage yield and response to N.

This study examined the consequences of combining N fertilizer to increase the production base with chemical curing for retaining forage quality in crested wheatgrass.

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Procedure

The Squaw Butte Experiment Station lies approximately 42 miles west of Burns, Ore. at an elevation of 4,600 ft. Areas now seeded to introduced grass species were once occupied by the big sagebrush-bunchgrass complex. This vegetative complex and associative soils have been studied and described by Eckert (1957). These soils are primarily sandy loams of basaltic origin and are often underlaid with a caliche hardpan at 12-24 inches. The annual precipitation is approximately 12 inches, most of which is received in the winter months. Summer and early fall is characterized by low precipitation.

Four treatments, control, N, paraquat[1], and N plus paraquat were assigned to plots within each of five replications in a randomized block design experiment. Treatments were applied to plots 6 x 20 ft in each of the crop years 1969, 1970, and 1971. Ammonium nitrate at 20 lb/acre elemental N was applied to the surface each fall. Paraquat at 0.2 lb/acre in 10 gal of water plus X-77[2] at 0.5% of total volume was applied with a 6-ft boom, bicycle sprayer. Dates of spray applications were June 20, 1969, June 18, 1970, and June 11, 1971.

Plots were sampled for herbage yields on or about August 1 of each year. An area 2 x 12 ft in the center of each treatment plot was harvested to ground level. Samples were oven dried in a forced air oven at 165°F. They were subsequently weighed, ground through a Wiley mill, and a subsample retained in air-tight jars. The subsample was analyzed for Kjeldahl-N.

Results and Discussion

Crop-year precipitation (Sept–June, inc.) in each year varied only slightly from the median amount of 11.0 inches (Table 1). Exceptionally heavy rains totaling 2.72 inches fell in August, 1968, following a record drought year and account for the significantly ($P<0.05$) greater herbage yield in 1969. This greater yield in 1969 was primarily responsible (through dilution) for the low crude protein concentrations in that year. Possibly, the earlier curing treatment (7-9 days) in 1971 accounts for the significantly higher mean crude protein concentrations in that year.

Table 1. Average herbage yield (g/24 ft²), herbage crude protein concentration (%), crude protein yield (g/24 ft²), and crop-year precipitation (inches) for each year.[1]

Item	Year 1969	1970	1971
Herbage yield	2096^c	918^a	1056^b
Crude protein conc.	4.7^a	5.1^b	6.2^c
Crude protein yield	23.3^c	11.3^a	14.5^b
Precipitation[2]	10.68	9.87	11.43

[1] Statistical significance at $P < 0.05$ denoted by unlike superscripts within row comparison.
[2] Crop-year (Sept. 1 to June 30, inc.).

Both N fertilizer and paraquat, singly and in combination, significantly influenced herbage yield ($P<0.05$)(Table 2). Yield of fertilized grasses was 80% greater than that of unfertilized grasses. Paraquat, whether alone or in combination with N, stopped growth when grasses had obtained about 78% of the year's production. With the combination treatment the net result was an increase in herbage yield of 40%.

Twenty pounds per acre of N did not significantly ($P>0.05$) increase the crude protein concentration of fall-harvested crested wheatgrass (Table 2). Significantly higher ($P<0.05$) crude protein concentration was present in harvested grass receiving paraquat treatment than in either fertilized or unfertilized grass.

While the total forage crop is important, the yield of high quality forage during the late summer early fall grazing period is of particular concern. Both paraquat and N and the combining of these two treatments significantly increased ($P<0.05$) the crude protein yield (Table 2). Combining the two treatments increased the crude protein yield 2.5 times over the control plots. The difference in digestible crude protein yield between naturally and chemically cured forage as a feed

[1] Paraquat (1,1'dimethyl-4,4'-bipyridinuim ion) has not been registered by the U.S. Environmental Protection Agency for this use.

[2] The use of a trade name does not imply its indorsement above that of similar products.

Table 2. Average herbage yield (g/24 ft²), crude protein concentrations (%), and crude protein yield (g/24 ft²) as influenced by treatments.[1]

Constituent	Control	Paraquat	Nitrogen	Paraquat + N
Herbage yield	818^b	633^a	1471^d	1148^c
Crude protein conc.	3.8^a	7.6^c	3.6^a	6.4^b
Crude protein yield	9.5^a	15.2^b	17.0^b	23.6^c

[1] Statistical significance ($P < 0.05$) denoted by unlike superscripts within row comparisons.

for grazing animals is actually greater than appears from Table 2. Wallace et al. (1966) reported higher digestion coefficients of most nutrients in chemically than in naturally cured grass forage by both in vitro and in vivo methods.

Crude protein yield, as influenced by treatment, varied significantly ($P<0.05$) by years. This interaction is shown in Figure 1. The interaction resulted from high crude protein yield in both fertilized and unfertilized grasses treated with paraquat in 1969. It is believed due to a carryover of soil N not utilized in the extreme drought year of 1968 and subsequently influencing yields in 1969. Carry over of N from 1968 is also substantiated by a lower yield response to applied N in 1969 (63% yield increase) than in the other 2 years (91 and 105% yield increase).

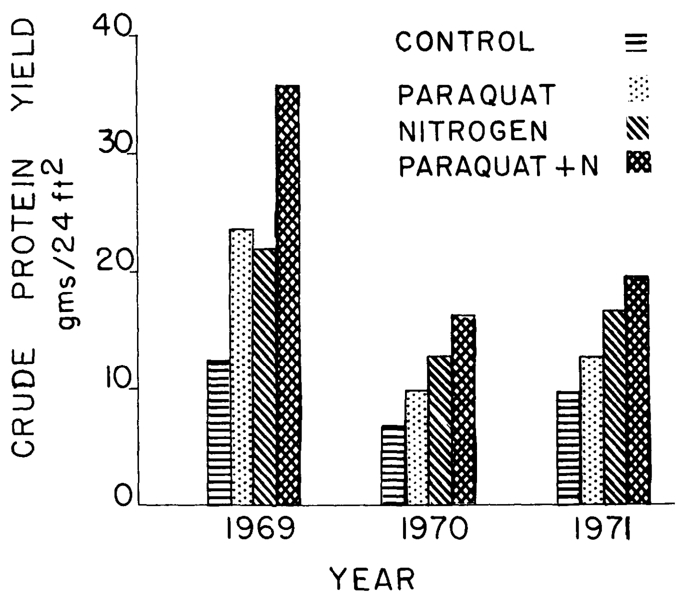

Fig. 1. *Crude protein yield of crested wheatgrass as influenced by nitrogen fertilization and paraquat.*

It is inferred from the results that N fertilizer for increasing yield and paraquat for curing the fertilized grass can be combined for increasing the yield and quality of late season forage. Should paraquat be cleared for this use, or a similar acting cleared chemical be found, the combination treatment offers an encouraging opportunity.

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Herbage Yields in Relation to Soil Water and Assimilated Nitrogen

J. F. CLINE AND W. H. RICKARD

Highlight: *Soil water, herbage assimilated nitrogen, and herbage were measured in the field and used to estimate the effectiveness of nitrogen fertilization to increase yields in cheatgrass communities. The application of regression analysis to estimate the amount of nitrogen fertilizer needed to increase herbage in relationship to available soil moisture is presented. When herbage nitrogen is in the range of 0.5 to 0.7% at the end of the spring growing season, nitrogen rather than soil water appears to limit herbage production.*

Studies of nitrogen fertilization of rangelands clearly show that added nitrogen is not effective in increasing herbage when soil water is limiting (Owensby et al. 1970; Stroehlein, 1968; Dahl, 1963).

In southeastern Washington the growth of cheatgrass (*Bromus tectorum*) and other alien winter annuals is closely related at least phenologically to the growth of winter wheat. Seeds germinate in the fall and plants mature in the spring with the onset of soil drought. It was anticipated that the soil water and nitrogen relationships that apply to wheat production would also apply to yields of the alien annuals.

Liggett (1959) fitted field data to several mathematical forms to predict the amount of nitrogen fertilizer needed to obtain maximal yields of dryland wheat in relation to the amount of available soil moisture. Ankerman and Waddoups (1968) use early spring measurement of soil water in conjunction with measurements of available soil nitrogen to recommend the amount of nitrogen fertilizer needed to produce maximal yields of winter wheat commensurate to available soil water.

Methods

Three abandoned fields located on the Atomic Energy Commission's Hanford Reservation, Benton County, Washington, were studied from 1968 to 71. The fields, located at different altitudes, 183, 305, and 518 m above sea level, each have supported more or less even swards of cheatgrass, intermixed with various amounts of annual forbs, especially tansy mustard (*Descurainea pinnata*) and tumble mustard (*Sisymbrium altissimum*) for nearly 30 years. Soil water was measured in the upper meter of soil profile at the beginning of the spring growing season and periodically thereafter throughout the growing season. Soil samples were taken at decimeter depth increments from two holes at each site using a sand auger. Soil water content was determined upon oven drying at 105°C for 48 hours. An estimate of the permanent wilting percentage was measured at −15 bars using a pressure membrane apparatus (Richards and Weaver, 1944).

Herbage was harvested periodically from 10 to 20, 0.1 m^2 randomly selected plots at each site throughout the growing season to obtain peak herbage yields. Herbage was dried at 60°C, its nitrogen content determined by Kjeldahl procedures (Jackson, 1962), and phosphorus content determined by procedure of Olsen and Dean (1965).

In 1971 additional plots were established at the field at the highest altitude to assess the effect of added nitrogen upon herbage production. This field was chosen for the nitrogen treatments because earlier studies had shown that this site had the greatest abundance of soil moisture. Five levels of nitrogen (0, 1.1, 3.3, 6.6 and 11.1 gN/m^2) were applied to 4 m^2 plots in early February, using NH_4NO_3 pellets distributed uniformly as possible over each plot by hand. Each treatment was replicated five times in a random block design.

Results and Discussion

The peak standing crops of herbage for the years 1969 to 71 are summarized in Table 1. The ranges varied between 127 and 328 g/m^2. The average yields over the 3-year period at the three different altitudes ranged between 221 and 273 g/m^2. The year-to-year variation was not as pronounced at the highest altitude as it was at the two lower elevations and is attributed to a more stable soil moisture supply.

Table 1. Herbage (g/m^2) and nitrogen content (%) and nitrogen utilization ratios in three different fields.

Item and year	Field altitude 183 m	305 m	518 m
Herbage[1]			
1969	328 ± 28	327 ± 26	226 ± 15
1970	165 ± 11	127 ± 8	208 ± 20
1971	No sample	211 ± 11	263 ± 38
Average	273	221	232
Nitrogen content[1]			
1969	1.19 ± .05	0.89 ± .09	0.52 ± 0.04
1970	1.46 ± .20	0.86 ± .08	0.75 ± 0.07
1971	No sample	0.95 ± .02	0.64 ± 0.06
Average	1.32	0.90	0.64
Nitrogen utilization ratio $\frac{\text{yield } (g/m^2)}{gN/m^2}$			
1969	66	91	173
1970	69	115	130
1971	No sample	105	155
Average	67	104	152

[1] Means and standard errors.

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Table 2. Soil chemical analyses from the upper decimeter of soil in cheatgrass communities.

Item	Field altitude		
	183 m	305 m	518 m
N (%)[1]	.11 ± .007	.094 ± .007	.073 ± .004
P (ppm)[1]	11 ± 1	31.4 ± 3.9	33.8 ± 1.4
K (ppm)[1]	1382 ± 90	1404 ± 99	1082 ± 47
pH (range)[1]	6.4 – 6.9	7.0 – 7.3	7.4 – 7.8
Sand (5)	38	37	31
Silt (%)	54	52	56
Clay (%)	8	11	13

[1] Means (n = 5) and standard errors.

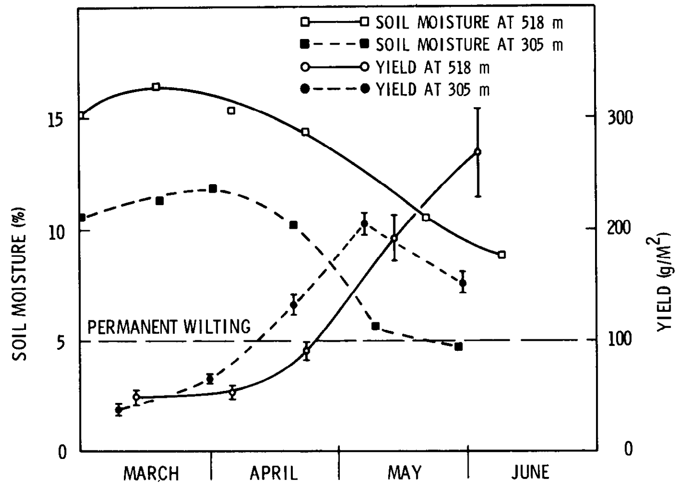

Fig. 1. *Moisture in the upper decimeter of soil and yield of standing herbage at two altitudes during the 1970 growing season.*

The nitrogen content of herbage at peak standing crop ranged between 0.52 and 1.46% (Table 1). The highest altitude consistently had the lowest nitrogen content and averaged only 0.64% over a 3-year period. When the herbage, expressed as g/m^2, is divided by the nitrogen assimilated by the herbage, expressed as gN/m^2, the most efficient use of nitrogen was made at the highest elevation, and the least efficient use was made at the lowest elevation. Chemical analyses of soil also showed that less nitrogen was present in the soil at the high altitude field (Table 2).

As expected, amount of soil water available for plant use varied greatly from year to year among the three different sites (Table 3). During the years 1968 to 71 the stored soil water ranged between 3.9 and 11.3 cm in the upper meter of soil profile. The driest year was 1968 and the wettest 1969. However, the average water use was similar at all altitudes. Some moisture percolated below 1 m deep at the high altitude field, and some soil water held at tensions above permanent wilting remained in the soil profile at the end of the spring growing season (Fig. 1). This lack of effective soil water usage is attributed to the paucity of available nitrogen to sustain a maximum yield.

During the years of study, soil water usage, measured as the yield in g/m^2, divided by the centimeters of available soil water lost from the soil profile, ranged between 19 and 26 at the high altitude field. However, the ranges were wider at the lower altitudes (Table 3). This indicates that over a several-year period soil water is not such a strong force in limiting herbage yields at the higher altitude as it is at the lower altitude.

To further illustrate the differences in soil water use at the medium and the high altitudes, the 1971 herbage growth curves and concomittant soil water depletion curves are shown in Figure 1. These curves show that peak production at the medium altitude occurred when soil water was depleted in May. The peak yield at the high altitude occurred in early June, but the soil profile at this time still contained some available water. It was concluded that herbage yield at the high altitude was limited by nitrogen rather than soil water. When the nitrogen content of herbage is about 0.64%, it seems that nitrogen rather than moisture is limiting herbage.

The field data were subjected to regression analyses to show the relationships of herbage yields to both nitrogen content of herbage and available soil water. The equation for soil water and yield Y (yield) = 29.7 + 27.6W (water) is significant at the 5% level (Equation 1). The equation for nitrogen content N (N in herbage) = −1.3 + 0.02Y (yield) is significant at the 5% level (Equation 2).

The equation Y (yield) = 71.1 + 41.1N (nitrogen) + 21.0W (water) derived from a stepwise linear regression showed that 71% of the variance in yield was due to nitrogen effect, 12% due to soil water effect and 17 is error not attributable to either soil water or nitrogen. To test the hypothesis that nitrogen was limiting herbage yields at the highest elevation, fertilizer was added before the onset of rapid spring growth. As expected, added nitrogen increased herbage yields (Table 4). The highest yield was obtained on plots with the most added fertilizer. The predicted yields in Table 4 were derived from the regressions formulated previously (Equations 1 and 2). There is generally good agreement between predicted and measured yields although occasional large discrepancies are also apparent. Further tests of this kind are needed on the low altitude fields to refine the predictability of nitrogen applications and herbage yields.

Table 3. Soil water use (cm) during growing seasons 1968-71 and calculated water efficiency ratios in three different fields.

Item and year	Field altitudes		
	183 m	305 m	518 m
Water used			
1968	No sample	4.2	3.9
1969	10.0	11.3	10.8
1970	7.1	10.5	9.0
1971	No sample	8.4	10.2
Average	8.55	8.3	8.5
Water efficiency ratio	yield g/m² / water (cm)		
1968	No sample	19.8	19.6
1969	38.2	28.8	20.6
1970	23.2	12.1	23.1
1971	No sample	25.1	25.8
Average	30.7	21.45	22.3

Table 4. Comparison of measured and predicted yields from nitrogen treated plots at 518 M altitude.

Fertilizer added (gN/m^2)	Yield (g/m^2)	
	Measured[1]	Predicted
1.1	241 ± 34	205
3.3	490 ± 60	324
6.6	480 ± 70	508
11.1	724 ± 65	755

[1] Expressed as means and standard errors.

The effect of added nitrogen on rangeland herbage is subject to considerable variability because of the vagaries of weather. The problem is to predict available soil water in advance of the growing season. Under the climatic regime of southeastern Washington, soil moisture is stored in the soil profile in fall and winter and is depleted in spring by evapotranspiration. By June there is little or no growth water available.

In this region available soil water can be measured by sampling in late February or early March. Abundant soil water at this time can be expected to result in good herbage yields later in the year. However, abundant precipitation during the growing season could also contribute to increases in herbage when winter storage was limited. Ankerman and Waddoups (1968) add 0.6 of the average rainfall during the growing season to the measured soil water. The following steps are suggested to determine the amount of nitrogen fertilizer needed to increase herbage yields in cheatgrass swards. (1) Measure the centimeters of available soil water and available nitrogen in the upper meter of soil prior to rapid growth. (2) Enter the centimeters of available soil water in Equation 1 and determine the yield for that quantity of water. (3) Enter the yield (g/m^2) obtained above (step 2) in Equation 2 and determine the amount of nitrogen expected in that amount of herbage. The difference between the total nitrogen needed to produce the herbage (step 3) and the measured available nitrogen is the amount of nitrogen to add. If the difference is 0 or a negative number, any added nitrogen would not be effective during that particular season. Nitrogen added to the soil and not used by plants during the same growing season may be lost by wind and water erosion, but some is likely to persist in the root zone and become available to plants the following year.

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Water Storage Capacity of Contour Furrows in Montana

EARL L. NEFF

Highlight: *A field study in eastern Montana related water storage capacity of contour furrows constructed by Model B furrowing machines to furrow age. New contour furrows have a water storage capacity of nearly 1 inch, but this decreases with time owing to natural weathering, intrafurrow dam failure, and furrow breaching. Contour furrows have an average effective life of 25 years, but this ranges from less than 20 years to more than 35 years, depending on initial construction. A new furrowing machine design is suggested that would leave intrafurrow dams of undisturbed soil material, resulting in furrows with either the same storage capacity but at a greatly reduced cost per acre, or over twice the storage capacity at about the same cost per acre as furrows built by a Model B machine.*

Mechanical land treatments have been applied to western rangelands for many years to reduce surface runoff, reduce sediment production, and increase desirable forage. These treatments provide surface water storage, which increases infiltration time and results in more soil water storage for plant use. Branson, et al. (1966) published a comprehensive literature review and results of mechanical treatment effects on rangeland in Wyoming, Montana, Colorado, New Mexico, Utah, and Arizona. They point out: "Although mechanical treatments have been applied extensively, relatively few published reports contain quantitative data on the results of such treatments." The investigation reported here was conducted in Montana to assess contour furrow water storage capacity and longevity.

Contour furrowing is the most common mechanical treatment applied to Montana rangelands on the public domain. While several different designs of furrowing machines have been used in the past, in more recent years the Model B contour furrower developed under the sponsorship of the Range Seeding Equipment Committee by the Equipment Development Center, U.S. Department of Agriculture, Forest Service, San Dimas, Calif., has been used almost exclusively. The Model B contour furrower constructs two furrows 6 to 10 inches deep and 20 to 25 inches wide on 5-foot centers. A ripper tooth precedes the furrowing discs and rips the soil 10 to 14 inches deep, and a dam-building device can be adjusted

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to construct dams within the furrows at any interval between 5 and 170 feet. Furrows sampled in this study had intrafurrow dams about every 15 feet.

In this study, a furrow was considered to be a furrow section between two intrafurrow dams. A failure occurred when either one of the dams failed, allowing water to drain into the adjacent furrow section, or the furrow itself was breached. In either case, failures usually progressed like toppling dominoes as the drainage from upslope failures exceeded the downslope storage capacity.

Procedure

Sample furrows were measured at five locations in Carter County, Montana—15 to 20 miles south of Ekalaka—and at two locations in Phillips County, Montana—one 15 miles and another 55 miles southwest of Malta. All locations were on panspot range sites. Furrow age ranged from 6 months to 11 years, and all were constructed by a Model B furrowing machine.

A series of measurements were made within the samples to determine furrow geometry. In general, furrows had trapezoidal cross sections, bottom widths that averaged 12 inches, and were on 5-ft centers. In computations of furrow storage capacity, it was assumed that all furrows conformed to these sample measurements. From this assumption, the volume available for storage is found by:

$$\text{Furrow volume} = \left[\frac{W+12}{2}\right](d)(L) \qquad (1)$$

where W is furrow width at minimum depth, d is furrow minimum depth, and L is furrow length. This volume is equal to some depth of precipitation falling directly into the furrow or:

Precipitation volume = $(W)(P)(L)$ = furrow volume

where P is precipitation depth. Therefore:

$$(W)(P)(L) = \left[\frac{W+12}{2}\right](d)(L) \qquad (2)$$

and

$$P = \frac{(W+12)d}{2W} = S_s, \text{ the furrow storage capacity} \qquad (3)$$

From the assumption that furrows were on 5-ft centers, the storage provided for the entire area was found by:

$$S = S_s\left[\frac{W}{60}\right] \qquad (4)$$

where S is area surface water storage. Inches were used as the unit of measurement in all cases.

A random walk technique was used to provide random sampling in furrowed areas. Four walks were generated using tables of random numbers, and each walk resulted in 50 samples in a 20- to 25-acre sampling area. Twenty-five random walks were made at the seven locations for an average of about three walks per location. Minimum depth and furrow width at minimum depth were measured at each sampling point. Storage at each point was computed using equations (2) and (4) assuming that furrow mean width was equal to the measured width at minimum depth. The individual points within each walk were averaged, and this average was considered to be a location sample. Furrows measured in the random walks were considered nonfunctional with zero storage if either the intrafurrow dams had failed or the furrow had been breached.

A rational approach was used to develop a mathematical relationship between the dependent variable, furrow storage, and the independent variables, furrow age and percentage of furrows that were effective. First, by definition, m = total number of furrows in an area; n = total number of effective furrows; t = age of furrows in years; $n = n_o$ at $t = 0$; and $\bar{s}$ = mean storage per effective furrow. Then,

$$\bar{s} = \frac{\sum_i S_i}{n} \qquad (5)$$

where S_i = storage in furrow i. Also, total storage per unit area S, at any time is given by:

$$S = \frac{n\bar{s}}{m} \qquad (6)$$

The rate of change in the number of effective furrows with time is given by the differential equation:

$$\frac{dn}{dt} = -\rho n \qquad (7)$$

where ρ is the probability of failure of any furrow. Integrating (7) gives:

$$\ln n = -\rho t + c \qquad (8)$$

or

$$n = e^{-(\rho t + c)} = e^{-\rho t}\, e^{c} \qquad (9)$$

where c is some integration constant. But when $t = 0$, $n = e^c = n_o$ by definition above. Substituting n_o for e^c in (9) gives:

$$n = n_o\, e^{-\rho t} \qquad (10)$$

The rate of change of storage in effective furrows with time is given by the differential equation:

$$\frac{d\bar{s}}{dt} = -\alpha\bar{s} \qquad (11)$$

where α is a decay constant. Integrating (11) gives:

$$\ln \bar{s} = \alpha t + c \qquad (12)$$

or

$$\bar{s} = e^{-\alpha t + c} = e^{-\alpha t}\, e^{c} \qquad (13)$$

But when $t = 0$, $\bar{s} = e^c = \bar{s}_o$ the initial storage. Substituting $\bar{s}_o$ in (13) gives:

$$\bar{s} = \bar{s}_o\, e^{-\alpha t} \qquad (14)$$

But $\bar{s} = S\frac{m}{n}$ from (6), which when substituted into (14) gives:

$$S = \bar{s}_o\left[\frac{n}{m}\right] e^{-\alpha t} \qquad (15)$$

Substituting (10) into (15) gives:

$$S = \bar{s}_o \frac{n_o}{m} e^{-(\alpha + \rho)t} \qquad (16)$$

If $\frac{n}{m}$ is symbolized by F and $\frac{n_o}{m}$ by F_o, then (15) can take the natural log form:

$$\ln \frac{S}{F} = \ln \bar{s}_o - \alpha t \qquad (17)$$

and (16) can take the form:

$$\ln S = \ln(\bar{s}_o F_o) - (\alpha + \rho)t \qquad (18)$$

Linear regression equations have the form:

$$Y = a + bX$$

where Y = the dependent variable; a = Y intercept when $X = 0$; b = slope of the regression line; and X = the independent variable. If a regression of $\ln \frac{S}{F}$ versus t is made, then from (17) $a = \ln \bar{s}_o$ and $b = \alpha$. Also, if a regression of $\ln S$ versus t is made, then from (18) $a = \ln(\bar{s}_o F_o)$ and $b = \alpha + \rho$. Regressions were made of data from the field samples and resulted in:

(19) $\ln \bar{s}_o = -0.003$, $\bar{s}_o = 0.997$ — $\alpha = 0.082$, $\ln(\bar{s}_o F_o) = 0.089$ (20)

(21) $\bar{s}_o F_o = 0.915$ — $\alpha + \rho = 0.108$ (22

Substituting (19) into (21):

$$0.997\,F_O = 0.915$$

$$F_O = 0.92 \quad (23)$$

Substituting (20) into (22):

$$0.082 + \rho = 0.108$$

$$\rho = 0.026 \quad (24)$$

Discussion

In theory, new contour furrows constructed by a Model B furrowing machine should average 8 inches deep, 23 inches wide, and provide almost 2.5 inches of water storage. However, the data reported here do not substantiate this much storage. From equation (6), the initial storage can be found by:

$$S_O = F_O\,\bar{s}_O = (0.92)\,(0.997) = 0.92 \text{ inch}$$

which is only 38% of the theoretical amount. This discrepancy is due to the difference between theoretical furrow depth and the depth actually constructed. Montana field data showed that furrows 6 months old averaged 3.7 inches deep and 20.6 inches wide. Observations indicate that these depths shallower than theoretical are caused by any one or a combination of three reasons: (1) Intrafurrow dams are constructed of loose, unconsolidated soil which, upon wetting and soaking, compact to one-half or less their original height; (2) Adverse soil structural or soil water conditions prevent the furrowing machine from digging to design depth; (3) Furrows are not constructed on the contour because of either rolling topography or improper machine operation. In either case, furrows built with a slope rapidly lose storage due to the domino effect of failures.

By far the most common cause of furrow storage loss is the settling of intrafurrow dams. When dams settle to less than one-half their original height, the minimum depth–(d in equation (3)–is reduced from the total furrow depth of 8 inches to the settled dam height. This, in turn, reduces the average initial water storage capacity of furrowed areas from 2.5 inches to 0.92 inch.

The problem with dams suggests a furrowing machine could be designed to provide intrafurrow dams of compacted material less subject to settling and erosion failures. A machine designed to lift the furrowing discs from the furrows at 15- to 20-ft intervals and leave furrow sections separated by 2 to 3 ft of undisturbed soil would result in furrows that were structurally stable and less subject to intrafurrow dam failure. Such furrows would have more than double the initial water storage capacity of furrows constructed by a Model B machine, because dams of undisturbed material would provide water storage to the full depth of the furrow. This increased water storage should also increase furrow stability because the dams would be overtopped less frequently and, when overtopped, the consolidated and vegetated material would be less subject to erosion. This can be demonstrated by equation (16). If it is assumed that s_O = 2.5 inches, that ρ is reduced by half to 0.013, that F_O remains at 0.92, and that α remains at 0.032, then equation (16) can be written:

$$S = (2.5)\,(0.92)\,e^{-0.095t}$$

From this, when t = 0, S_0 = 2.3 inches; when t = 10 years, S_{10} = 0.89; when t = 20 years, S_{20} = 0.38; and when t = 30 years, S_{30} = 0.13 inch. These estimates compare with estimates for the present Model B furrows of S_0 = 0.92, S_{10} = 0.31, S_{20} = 0.10, and S_{30} = 0.03 inch.

Since the Model B machine constructs furrows with an average water storage capacity of 0.92 inch, it might be assumed that this storage amount is adequate for rangeland treatment. If this is the case, a machine designed to eliminate the dam settling problem could provide about 1 inch of storage by constructing furrows 4 inches deep and 20 inches wide. In this situation, equation (16) gives: S_0 = 0.98, S_{10} = 0.38, S_{20} = 0.16, and S_{30} = 0.06. Such a furrowing machine would have a much smaller draft requirement than Model B machines, which are pulled by tractors with power equivalent to a Caterpillar D-7 or D-8. A machine pulled by an ordinary farm tractor could construct furrows for about $12 per acre, as compared to the estimated $15 to $20 per acre for furrows constructed by Model B machines.

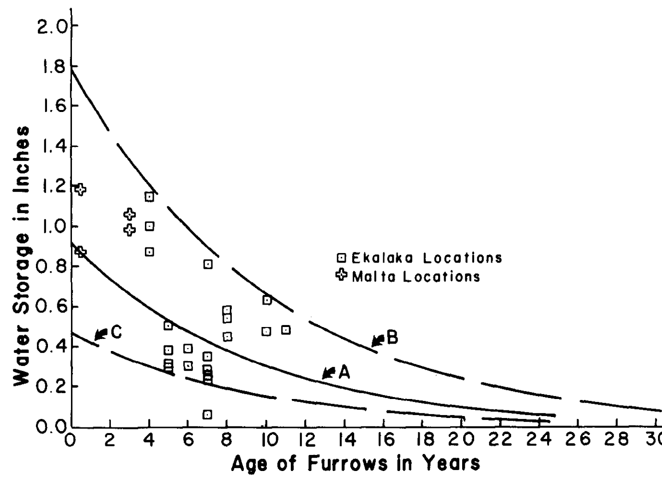

Fig. 1. *Water storage versus age of furrows.*

Furrow longevity is difficult to assess, but some inferences can be drawn from statistical analysis of the Montana field data. Figure 1 is a plotting of water storage capacity versus furrow age. Curve A is the regression line of ln S versus age, and curves B and C are the regression line plus and minus one standard deviation, respectively. These curves are interpreted to indicate that for any given age, curve A is the statistically most probable value for storage, and there is a 67% chance that the true value lies between curve B and C. Also, there is a 16-2/3% chance that the true value will be greater than curve B and a corresponding 16-2/3% chance that it will be less than curve C. If an arbitrary criterion is established that furrows remain effective only as long as they provide 0.05 inch of water storage, Figure 1 indicates that, on the average, (curve A) furrows remain effective for about 25 years. However, about one-sixth of all furrow projects will be effective for less than 20 years and one-sixth will remain effective longer than 35 years.

Effective life, as used here, refers only to the water storage capacity. Longevity of another furrowing objective, increasing desirable forage, is beyond the scope of this study. However, if proper grazing practices are followed, the effect on forage should be sustained longer than the effect on surface water storage, due to vegetation establishment and soil physical and chemical changes brought about by contour furrowing.

Summary

Contour furrowing is an effective method of increasing water storage on rangelands in Montana. New furrows constructed by a Model B furrowing machine have an average storage capacity of nearly 1 inch. Storage decreases with time and is dependent not only on age but also on initial construction conditions and on the probability of individual furrow failure as expressed by:

$$S = \bar{s}_o F_o e^{-(\alpha + \rho) t}$$

On the average, contour furrows will have an effective life ($S > 0.05$ inch) of 25 years, but there is a one-sixth chance that effective life will be less than 20 years or more than 35 years.

A furrowing machine designed in such a way that furrow sections are separated by compacted or undisturbed soil would provide furrows that either (a) had initial water storage capacity more than twice that of furrows constructed by Model B machines, or (b) had the same storage capacity as those built by a Model B machine, but at a much smaller cost per acre. In either case, storage loss due to intrafurrow dam failures would be greatly reduced, resulting in longer effective life.

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Second Call for Papers

27th Annual Meeting, SRM
February 3-8, 1974, Tucson, Arizona

The objective of the Program Committee for the 1974 Annual Meeting is a stimulating program of important topics which will provide something of value and interest to all those who attend. To accomplish this objective, the format for the meeting will include both invited and volunteer papers; it will also provide a forum for examining controversial issues and for the expression of ideas. The committee solicits members *and nonmembers* to volunteer papers reporting their work, their research, and their ideas. Although papers on any subject relevant to range science and range management, or the affairs of the Society, will be considered, papers representing new knowledge and fresh ideas are especially encouraged. A session of volunteer papers titled "Viewpoints" is being arranged to accommodate those wishing to express their particular viewpoint orally to the Society.

The Program Committee will carefully screen all volunteer papers and select only those that provide reasonable assurance of meeting the high standards of quality that the Society expects. The committee will attempt to accommodate papers on any subject matter.

Procedure—Those wishing to present papers at the 27th Annual Meeting should consider only topics that can be presented with an allocated time of 15 minutes. They should provide the following: (1) title of paper, (2) name and affiliation of author(s), (3) name of individual who will present the paper, (4) name and address of author to whom correspondence should be addressed, (5) a preliminary abstract of not less than 250 nor more than 500 words, and (6) a supporting statement indicating the significance of the offered paper and the subject matter area(s) under which the author thinks the paper should be classified. For research papers, this statement should also indicate the relative amount of data supporting the paper (e.g., years of study, etc.). All illustrative material must be in the form of 2x2-inch slides for use in Carousel projectors.

Deadlines—Three (3) copies of the preliminary abstract and supporting statement must be in the hands of the Program Committee chairman *not later than* **August 15, 1973** (*October 5 for student papers*). Authors will be notified of acceptance or rejection of their paper by **October 1, 1973** (*November 1 for student papers*). Final abstracts for all papers must *not exceed 300 words* and must be received by the Program Committee by **November 15, 1973.**

Abstracts, inquiries, and correspondence relevant to the program should be addressed to: **James O. Klemmedson, Chairman, SRM Program Committee, Department of Watershed Management, University of Arizona, Tucson, Arizona 85721.**

TECHNICAL NOTES

Modified Step-point System for Botanical Composition and Basal Cover Estimates

CLENTON E. OWENSBY

Highlight: *Instructions for use and assembly are presented for a modified step-point sampler. Modifications were made to eliminate bias and to increase ease of use.*

Basal-hit, single-point sampling in botanical census has been shown to be effective and efficient (Goodall, 1952). Evans and Love (1957), describing the step-point method of sampling, concluded that the method's accuracy and objectivity made it suitable for valid analysis of field research plots.

Step-point sampling uses a single pin lowered perpendicularly to the soil surface through a notch in the toe of the sampler's boot at a 30° angle to the ground. Basal or foliage hits may be recorded. Nonplant hits are recorded as misses and the species nearest to the point in a forward, 180° arc is recorded. Information is obtained for basal or foliage cover of individual species, their collective total, and for percentage composition. An estimated frequency may be obtained by grouping points.

Subconscious selection of plants that affects pin placement is a serious defect (Cain and Castro, 1959; Goodall, 1952), which random selection of a single pin from a point frame with several pins would alleviate (Goodall, 1952). Using a single pin instead of groups of pins reduces the number of points needed for comparable accuracy (Blackman, 1935; Goodall, 1952; Greig-Smith, 1957). Single pin measurements require one-third as many points as groups of pins do for comparable accuracy (Goodall, 1952), and time required is reduced to one-sixth or one-eighth that required for the point-frame method (Evans and Love, 1957).

The point-frame modification presented here seeks to eliminate subconscious bias in point placement and to make single-point sampling easier.

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Point-frame Design

The basic design of the point frame is shown in Figure 1. The sampling point (a) is offset from the initial ground contact (b) to alleviate subconscious placement by the sampler. The distance it is offset varies with the angle the point rod makes with the horizontal. The inset shows the

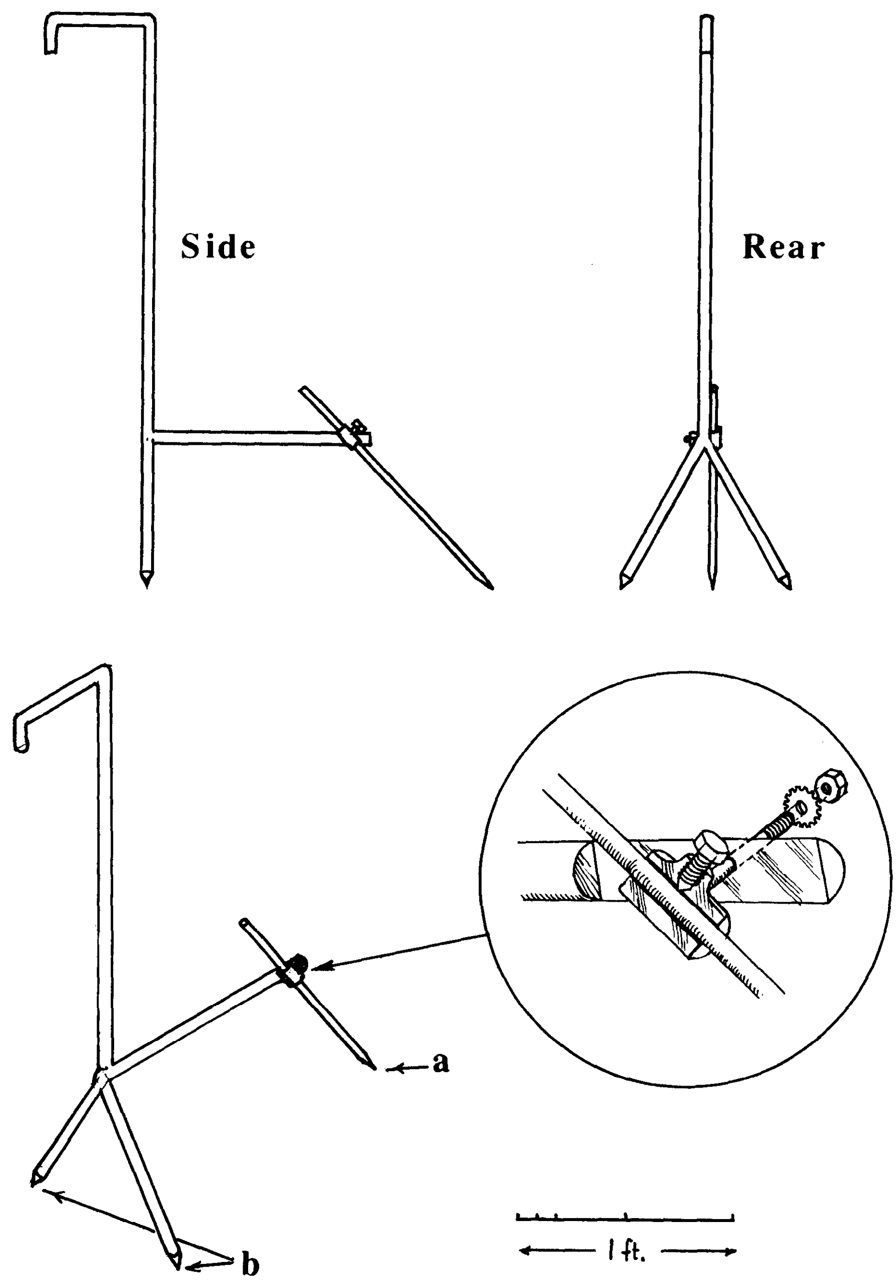

Fig. 1. *Diagram of the modified step-point sampler (*a*–sample point,* b*–initial contact points).*

pivot point mechanism, which adjusts horizontal angle and sample rod length. That enables the sampler to vary sample rod angle and length for sampling different vegetative types. Tinney et al. (1937) indicated better accuracy with an inclined point. Two legs sharpened at the tip (b) are used to eliminate side movement of the sample rod as it moves through the vegetation. Construction is of steel rod or tubular steel with the sample rod being hardened steel with a long-tapered, fine point.

Procedure

The sampler follows a designated line through the plot area. One leg of the point frame is placed at the end of the sampler's boot each time his right (or left) foot hits the ground. The point frame is leaned back towards the sampler on initial ground contact and is leaned forward until point contact is made with a plant crown or bare soil. That enables the sampler to watch its progress much the same as with a point frame. Species recorded are those whose bases are contacted by the point. If no basal hit occurs, the species nearest the point forward (180° arc) is recorded. Basal hit or miss information is also recorded for basal cover estimates. Species and basal cover information are coded by number for ease in computer analysis.

Preliminary use of the device showed it to be easily used with two samplers and a recorder. The two samplers read from opposite feet with one moving while the other was reading the sample point. That permitted the samplers to read 3,000 to 4,000 points per 7-hour day, which covered about 60 acres in the experimental area. Monotony reduced the number taken. To remain alert and avoid inaccurate work, frequent rest breaks are recommended. An average of 2,500 to 3,000 points per day, we think, is realistic.

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Pine Sawdust as a Roughage Replacement in Gestating Beef Heifer Rations

A. L. SLYTER AND L. D. KAMSTRA

Highlight: *No abortive tendencies were noted with Angus X Hereford crossbred heifers when fed a corn-roughage ration containing 25% sawdust during the last one-third of the pregnancy period. Inclusion of sawdust in the ration did not affect the calving difficulty score or birth weights.*

Previous studies have shown that pine sawdust levels up to 10% of the total ration presented no visible toxicity symptoms with calves fed a growing ration during a 90-day period (Kamstra and Minyard, 1970). Also, no detrimental effects on either feedlot performance or carcasses were shown with cattle fed high energy rations for 115 days when sawdust was used to replace half the alfalfa roughage in a 90% concentrate ration. (Slyter and Kamstra, 1971b).

Sawdust has been suggested as a possible roughage in wintering rations for breeding stock in the range areas when other roughage materials are in short supply. The purpose of this study was to ascertain whether any toxicity might result from incorporating sawdust in wintering rations for pregnant heifers. Special emphasis was given to the possibility of embryonic abortion, since pine needles have been suggested as a causitive factor by Canadian researchers as early as 1927 (Bruce, 1927).

Materials and Methods

Twelve Angus X Hereford crossbred pregnant heifers were randomly allotted to two pens of six each. Experimental rations consisted of either 20 lb per head daily of grass and alfalfa loose hay or 20 lb of a mixed ration consisting of 25% ground corn, 25% sawdust, and 50% ground alfalfa hay starting December 24, 1970. These rations were calculated to be approximately equivalent in TDN and crude protein levels. Trace mineral salt and dicalcium phosphate (50-50) were provided free choice. Animals were weighed monthly, calves were weighed at birth, and calving difficulty was subjectively scored (Table 1, footnote). Animals were taken off treatment at calving.

The authors are with the Department of Animal Science, South Dakota State University, Brookings.

The study was conducted at the U.S. Department of Agriculture Newell Field Station, Newell, South Dakota. The article is published with the approval of the Director of the South Dakota Agricultural Experiment Station as Publication No. 1062 of the Journal Series.

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Results and Discussion

No abortive tendencies were observed during this trial. The first calf was born February 18 and the last calf on June 8. Sawdust feeding was terminated on March 16, since only two animals remained on each treatment. The average calving date was March 23 and March 22 for the control and sawdust groups, respectively. One set of twins was born in the sawdust-fed group, although not attributable to sawdust feeding. Both rations supported adequate weight gains during the period fed (Table 1).

No significant differences were noted in calving difficulty or calf birth weights (Table 1).

Table 1. Weight changes and calving results.

Ration	Control	25% Sawdust
Number in lot	6	6
Average wt 12-24-70	878.3	883.3
Average wt 03-16-71[1]	904.2	925.8
Average calving score[2]	1.7	2.3
Average birth wt of calves	56.7	59.4[3]

[1] Weights included four heifers post-calving and two pre-calving in each lot.
[2] Scored as follows: 1 = no difficulty; 2 = slightly difficult; 3 = difficult, calf puller needed; 4 = extremely difficult.
[3] Includes one set of twins.

Previous work (Kamstra and Minyard, 1970) would suggest that not only is sawdust, fed at levels up to 25% of the ration, nontoxic, but it serves as a nutritive component as well. They found that fecal excretion of fiber did not increase proportionally with increases in sawdust in the ration. Increasing the level of sawdust from zero to 5% increased fecal fiber excretion from 39.6% to 40.0%; but when sawdust was increased to 25% of the ration, the feces contained only 46.6% fiber. In vitro dry matter digestibility ranged from 6 to 10% when used as the only substrate during a 48-hour fermentation period. This would suggest that stock could not be maintained on high sawdust rations unless the sawdust is treated to increase utilization, even if abortive tendencies or other toxicity factors were not critical.

Summary and Conclusions

Feeding a ration containing 25% raw pine sawdust to first-calf beef heifers during the last one-third of gestation resulted in no abortion or intake problems. No differences were noted in calf birth weights or calving difficulty in heifers fed the control or sawdust rations. Based on these results, it would appear that sawdust could serve as a roughage source in wintering rations for breeding stock up to 25% of the total ration.

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Chromatographic Identification of Big Sagebrush Seed

DAVID L. HANKS AND KENT R. JORGENSEN

Highlight: *Paper and thin-layer chromatography of big sagebrush seed provides a rapid, simple means of identifying more palatable forms of this shrub. Methanol extraction of seed for 24 hr followed by two-dimensional paper (n-butanol:acetone:water, 4:1:3; acetic acid: water; 15:85) or single-dimensional thin-layer chromatography (chloroform:methanol:water; 85:10:5) reveals distinctive differences between* Artemisia tridentata *subsp.* tridentata *and the more palatable subsp.* vaseyana *and* wyomingensis. *A bright, iridescent blue spot characterizes the more palatable subspecies; the same spot is much smaller and duller in* A. tridentata *subsp.* tridentata.

Utilization of big sagebrush (*Artemisia tridentata*) as a forage shrub in current range improvement projects has become more promising with the development of techniques by which the more palatable forms of this shrub can be identified (Hanks et al., 1971). Under properly controlled conditions, these forms (subsp. *vaseyana* and *wyomingensis*) can then be used as a seed source for reseeding programs where shrubs are desired for which animals show some grazing preference. However, all too frequently the sources of available seed are from populations where the preferential utilization by big game or livestock is unknown. Under these circumstances, a means of detecting the types of big sagebrush from which the seed lots were collected would be a valuable aid in the proper management of reseeding programs. Taylor et al. (1964) pointed out the differential fluorescence between moist *A. tridentata tridentata* and *A. tridentata vaseyana* seeds. When viewed under long wave ultraviolet light the *A. tridentata vaseyana* seeds fluoresce more brightly. The following procedure describes a more definitive means of distinguishing subsp. *vaseyana* and *wyomingensis* seed from those of the less palatable subsp. *tridentata.*

One-half gram seed samples (98% purity) are placed in vials containing 10 ml absolute methanol and allowed to extract for 24 hr. The extract is decanted and evaporated to a final volume of 1.0 ml. Two-dimension chromatograms are developed by the application of 40 μl of this extract to Whatmann 3 MM chromatographic paper[1] using butanol:acetone: water (4:1:3) as the first solvent system and acetic acid:water (15:85) as the second. The appearance of a bright, iridescent blue spot, R_f = .54/.78

$$\left(R_f = \frac{\text{distance of spot from origin}}{\text{distance of solvent front from origin}}\right)$$

under ultraviolet light is indicative of either subsp. *vaseyana* or *wyomingensis* seed. If the above spot is present but lacking in iridescence, the seed belongs to the subsp. *tridentata.*

If instant thin-layer chromatography (ITLC) apparatus is available, the time required for seed identification is greatly reduced. The solvent system, chloroform: methanol:water (85:10:5), with silica gel-impregnated Gelman ITLC strips produces a band analogous to the spot described above with an R_f = .67.

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At the time the article was written, David Hanks was plant physiologist, U.S. Department of Agriculture, Forest Service, stationed at the Great Basin Experimental Area, Ephraim, Utah. At present he is assistant professor of microbiology, Northeast Missouri State University, Kirksville. Kent Jorgensen is seed technician, Utah Division of Wildlife Resources, P.O. Box 276, Ephraim.

Federal aid in wildlife restoration funds was provided through Project W-82-R.

Manuscript received January 27, 1973.

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

Small Lysimeters for Measurement of Water Use and Herbage Yield

W. T. HINDS

Highlight: *Small weighing lysimeters provide a useful tool for investigating simultaneously soil water use and plant productivity in annual grasslands. Details of construction, sensitivity and accuracy of weighing, and field and harvest techniques are given. PVC irrigation pipe is used for both the lysimeter and its sleeve–5 inch and 6 inch nominal diameter, respectively. Weight changes equivalent to .002 inch (.05 mm) can be detected, allowing diurnal water use to be determined if desired. Comparisons using shoot harvest and soil water use for Spring, 1971, show good agreement between the lysimeters and the field.*

Weighing lysimeters can provide useful information concerning water relations because they physically confine soil water. However, most lysimeter installations employ relatively large lysimeters to simulate surrounding community conditions, thereby precluding sufficient replication to estimate variability within communities. In Russia, the State Hydrological Institute has carried out extensive experimentation with lysimeters of various sizes, concluding that small lysimeters need not substantially distort either the water or thermal regimes within the lysimeter with respect to the field (Konstantinov, 1966). The lysimeters specified by the Russian Hydrological Institute were 0.05 m^2 in surface area, 0.5 m deep, and were constructed with steel walls. Smaller diameters were discouraged because the conductivity of the walls disturbed the temperature conditions with the lysimeter, while shallower lysimeters were precluded by the expected depth of rooting of the experimental grasses (barley, wheat, and rye). This paper describes a modification of the USSR small lysimeter and discusses some simple field techniques for meaningful replication in the field.

Construction of the Lysimeters

The major disadvantage of small lysimeters for field use is their small surface-to-edge ratio, allowing a greater potential for thermal distortions in the enclosed volume of soil. In the Russian lysimeters,

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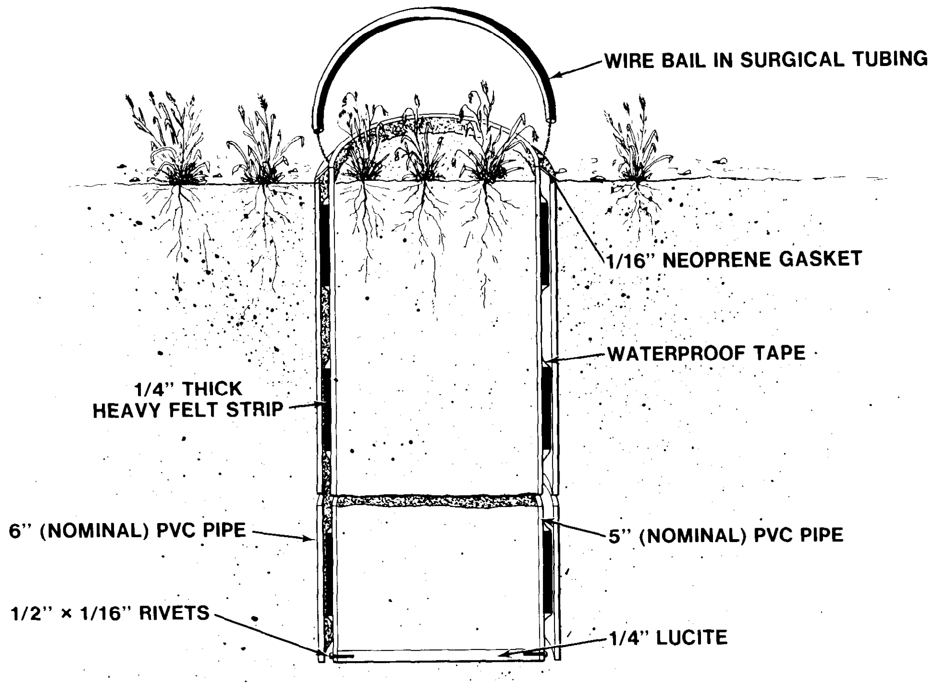

Fig. 1. *Details of construction of small lysimeter. The lysimeters discussed in the text were 60 cm deep, but shallow-rooted plants may not require that depth.*

thermal disturbance was induced by two factors: the high conductivity of the metal walls of the lysimeter and its sleeve; and the air gap between the lysimeter and sleeve. The disadvantages of metal can be avoided by using plastic irrigation pipe (polyvinyl chloride) for both the lysimeter and the sleeve. Nominal 5-inch diameter pipe has an outside diameter (OD) of 5.65 inches (14.4 cm) and an inside diameter (ID) of 5.2 inches (13.2 cm), providing an internal cross section of 138 cm^2. Three or four strips of 0.25-inch-thick felt, about a quarter to a half inch wide, taped around the outer walls of the lysimeter, form "O" rings for a snug fit with the inner walls of the sleeve, which is nominal 6-inch diameter irrigation pipe with an ID of 6.2 inches (15.7 cm). The felt should be covered with waterproof tape, to prevent absorption of water in any form and the tape lubricated with oil or hard grease if necessary. Finally, a neoprene annulus just smaller in ID than the OD of the lysimeter, with an OD just greater than the OD of the sleeve, serves as a shield over the gap between lysimeter and sleeve, preventing wind, rain, and radiation from entering the gap. This series of baffles prevents convection currents between the lysimeter and its sleeve, encouraging horizontal isotherms within the lysimeter, just as in the field. The entire array of baffles and gasket is removed with the lysimeter for weighing. Figure 1 is a detailed cross section of the modified lysimeter.

Field Techniques

Installation of lysimeters in stone-free soil is a simple operation using a screw-type power auger to dig a hole the required depth. The diameter of a 7-inch hole is generally somewhat less than the OD of the 6-inch piping (6.7 inches or 17.0 cm) used for the sleeve, so the sleeve slices off a small amount of soil which must be cleared out of the hole (an ice cream scoop is handy for this). The lysimeter can then be inserted in the sleeve and the annular gasket smoothed as necessary. The entire procedure is more readily accomplished in moist soil rather than dry.

Placing soil in the lysimeters presents much the same problems faced in placing soil in garden pots. In relatively homogeneous soils without well developed horizons, dry soil can be poured into the lysimeter while bumping the lysimeter vigorously to remove excess air. The final bulk density can be controlled by varying the screening of the dry soil before use. Table 1 shows bulk density with different screen size on a sandy loam. Finely screened soil should be added slowly and bumped around in the lysimeter until it feels firm to the touch, lest excess air in the soil be displaced during wetting, causing extensive shrinking.

Table 1. Bulk densities (g/cm³) attainable as a function of screening size (mesh/inch) of the dry soil.

Screen size	Bulk density
2	1.25[1]
8	1.35
20	1.45

[1] Field conditions.

These lysimeters weigh approximately 35 pounds at field capacity. A portable scale with 25 kg capacity and 5 gram resolution[1] provides sufficient accuracy for determining water losses of 0.002 inch (0.05 mm) from the surface area of the lysimeter. If stationary and covered, this scale will weigh a calibration weight of 8.000 kg to within ±5 grams for periods approaching a year. Weighings of this sensitivity, however, *must* be shielded from wind; otherwise, the variability of the weighings may be increased by factors of five or ten.

To duplicate field conditions of grassland surfaces, soil cores can be taken, using a sharpened section of the 5-inch PVC pipe. The soil core slides readily into the lysimeter when pressed with a heavy weight placed on a plywood circle on top of the core. The maximum practical depth of the core probably depends on soil texture and moisture; for sandy loam, 30 cm was very difficult, but 10 cm was easy. The wet soil in the lysimeter must be "fluffed up" at its surface prior to core insertions to assist hydraulic contact between the core and the underlying lysimeter soil.

Total water loss is readily measured as evaporation from unvegetated soil surfaces and evapotranspiration from vegetated lysimeters. Unvegetated lysimeters are prepared by removing living plants, leaving any mulch intact, before installing them in the field. Comparing water losses from vegetated and unvegetated lysimeters gives the transpirational loss.

Soil temperatures and water potential can be monitored in as great detail as desired, merely by placing thermistors, thermocouples, or psychrometers at the desired depth as the lysimeters are filled.

Herbage yields within the lysimeters are measured by harvesting, but the precision of estimation is generally not the same for roots and shoots. Root estimates are obtained from samples of the soil and cores to be placed in the lysimeters. The samples are washed through, say, a 20-mesh/inch screen and floating root material collected for weighing and ashing necessary to account for soil particles held by the roots. After the period of study, the soil is washed out of the lysimeters with a high pressure water nozzle, with the soil again passing through a 20-mesh/inch screen—this collects all particles of 20-mesh size and larger. This material is then floated in water to separate root material for drying and ashing, just as was the "background" sample. The difference is root growth in the lysimeter, but with a larger standard error than for shoot growth, which is

[1] Maco model 25, is available from Mantes Scale Co., San Francisco, California. Brand names are for reader's convenience and do not constitute endorsement of the product.

Table 2. Average *Bromus tectorum* shoot production (g/m²) and total water loss (cm) estimated from lysimeters and in the field. Spring 1971, in a field at 1.700 ft elevation.

Location	Shoot production[1]	Water loss[1]
Lysimeter	156 ± 18	16.9 ± 0.6
Field	170 ± 24	16.5 ± 0.8

[1] Numbers following ± are standard errors.

estimated merely by clipping the plants from some cores when preparing the lysimeters and just before washing the soil out of the lysimeters.

Table 2 compares data from the lysimeters and from the field. The field water loss (determined gravimetrically) and herbage yields are very close to those from the lysimeter measurements in both average and variability. Not shown is the precision attainable from periodic weighings—13 lysimeters yielded an average standard error of 0.017 cm/day (9% of the mean) from 10 weighings in 60 days.

Conclusions

The small lysimeters used in groups provide a precise picture of water use during the season and an accurate total for the season. Likewise, the productivity in the lysimeters reflected both the average herbage yield and the natural variability encountered in the field. The lysimeters are not expensive—PVC pipe costs about $1/ft, and construction of each lysimeter takes about 2 hours of shop time. The data attainable through using several to many of these small lysimeters are unparalleled by other lysimeter techniques and consequently offer a potential for new insights into water relations and productivity in annual grasslands with only a modest capital investment.

Literature Cited

Konstantinov, A. R. 1966. Evaporation in Nature. Available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151, $8.36; translated from the Russian.

VIEWPOINT

A Student's Views on the Future of the Society for Range Management

RICHARD F. MILLER

As a student I am concerned with the future role that the Society for Range Management will play. I believe that the success of range management very much depends upon the strength of this professional organization. Working as individuals we have little chance of making much progress. Working as a unified group through the Society for Range Management we have the opportunity to manage rangeland resources on an ecological basis rather than a political one. The following four points I believe to be essential in managing range resources.

The first of these is adapting to change. As a society of professionals, we must become sensitive to demands and needs placed upon rangeland resources. These needs and demands are constantly changing with time. As the needs of society shift, the demands on range resources shift. To be effective we must adapt ourselves to these constant changes. We should try to project the future by looking at past and present trends. But even then we can get only a vague idea of things to come.

The second point is the image of a rangeman. I believe that our present image limits our full potential as rangeland resource ecologists. A large portion of the general public isn't really sure what a rangeman is. Many special interest groups look at us as livestock managers. Too often we simply manage range resources to suit the needs for livestock production. This creates an image that not only limits our acceptance by other professionals, but even more limits our influence as professionals to the public. I would like to see us project the image of Rangeland Resource Ecologists; professionals who can look at the entire picture and fit the land potentials, on a sound ecological basis, to the needs of the public.

The point is that we must become more influential in the public eye. A large portion of today's management is nothing but legislative fiat. Decisions are based on emotions that obscure the facts. We must base our decisions and statements on sound ecological facts. We must use the correct timing and place for introducing ideas and objectives if they are to have an impact. And, as professionals, we must avoid emotionalism, a tool that is tough to control.

Thirdly, we should become effective in integrating our profession with other professional fields. Sound environmental management requires multiple inputs from such areas as range management, geology, forest management, wildlife management, political science, social science, and a long list of others. Maybe I'm a little biased, but I think the range ecologist certainly has the qualities, with his broad background, to lead such a group.

The last and final point: What are our, the Society for Range Management, goals? I'm sure most of us could state goals that are so broad that we could all agree on them. For example, "To improve the environmental quality and at the same time harvest optimum levels of multiple products on the rangelands." Improvement of environmental quality sounds pretty good, but what is environmental quality? Does it mean clean air or unpolluted waters? What is environmental quality to a dune buggy fanatic may differ considerably from the environmental quality expected by someone who enjoys the quiet and beauty of an unspoiled desert. To many people, environmental quality is just knowing something is there, like the wild horse, even though they may never see it. People get a certain amount of inner satisfaction just by knowing this entity in the environment exists.

For the Society for Range Management to be effective in manipulating sound ecological management, we must work together. We must agree upon a set of goals that we have pinned down and defined. It is extremely difficult to lay down a set of objectives when we have no definable goals.

The author is a graduate research assistant, Rangeland Resources Program, Oregon State University, Corvallis.

BOOK REVIEWS

Key to North American Waterfowl. By Stephen R. Wylie and Stewart S. Furlong, illustrated by Jack R. Schroeder. Livingston Publishing Co., 18-20 Hampstead Circle, Wynnewood, Penna. 19096. 1972. $3.95.

This book which presents 46 colored plates of waterfowl species common to North America has both strong and weak points. Printed on a plastic, polyolefin paper-like material, it justifies the claims put forth on its durability. I personally carried a copy into the field during most of the hunting season. It got both wet and dirty on several occasions, but was readily cleaned up by wiping it off with a clean damp cloth. The only fading was the printing on the back which simply "wore off" the "olefin paper" where it had been folded and carried in a pocket. It would be a great advantage to the user if the booklet were put out in a pocket size edition. It appears this could easily be done by simply cutting each page horizontally in two before stapling the booklet together.

The book title is a misnomor in being called a "key." Arrangement of the species follows the classification proposed by Delacour, but no dichotomous description is given for species identification. More appropriately, it should be termed a "field guide" or some other more appropriate name.

The introductory material, including Mr. Gabrielson's preface, emphasizes the premise that the booklet is largely intended for use by waterfowl hunters. The colored plates, which are of species in winter plumage, are excellent. The authors mention that eclipse plumage descriptions are beyond the scope of this book. It is around this very point, however, that the main weakness of this book appears. A large percentage of the waterfowl, particularly in the northern tiers of states, are hunted in eclipse plumage not in winter, or as shown for the ring-necked duck or cinnamon teal, in spring breeding plumage. Thus, the booklet does not fully serve the audience for which it is intended. In fairness to the authors, it should be pointed out that most waterfowl field guides have this same shortcoming. Also, one of the most helpful items for identification purposes would be a pictorial insert of a wing with attention drawn to speculum details.

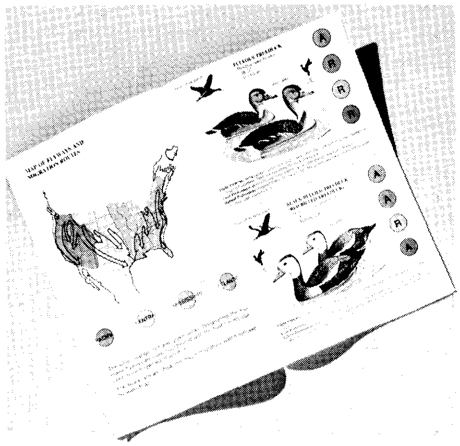

Fig. 1. *Pages from* Key to North American Waterfowl *showing arrangement of information on birds.*

The book presents a map of the flyway migration routes and then uses a series of colored circles to code abundance and locations frequented by a species, rather than using the characteristic distribution map (Fig. 1). I believe this generalization detracts from the book and is so nonspecific as to where you might expect to encounter species that it might be useless. For example, the Ross' Goose and the Emperor Goose have exactly the same rating on distribution and abundance. It points out that the Ross' Goose winters almost exclusively in central California, while it fails to point out that the Emperor Goose stays primarily in the Aleutian Islands or southwest coast of Alaska, with only a few stragglers reaching as far south as California along the shores of the Pacific Coast.

The cost of the book at $3.95 is expensive for this type of field guide. The durability, however, may justify the cost, as getting ordinarypaper field guides wet only once usually ruins them. I would suspect that care should be used to keep this polyolefin guide away from heat or flame.—*Pat O. Currie,* Fort Collins, Colo.

Desert Biology. Volume I. Ed. by G. W. Brown, Jr. Academic Press, New York, N. Y. 10003. 635 p. 1972. $29.50.

This book provides a wealth of information concerning the deserts of the world. It is divided into eleven chapters covering such diverse topics as climates of deserts, geology, evolution and biology of desert vegetation and plants, biology of desert amphibians and reptiles, temperature regulation in desert birds and mammals, desert limnology and human adaptations to desert environments. Each topic is covered by a recognized authority on the subject.

The book suffers somewhat from a characteristic common to multi-authored works: uneven treatment of material. The opening chapter is an interesting but very general description of a desert in the Sudan. This is in contrast to the chapter on desert amphibians and reptiles, which covers 161 pages, including some 56 pages of reference. For those interested in the botanical phases of deserts, less than 100 pages, or about 1/6 of the book, is devoted to these subjects. For the range worker there is little information concerning the natural resources or value of deserts from the standpoint of grazing. However, the purpose of the book as stated in the preface was to "Aid man's understanding and appreciation of the arid environment....if he is to utilize and not abuse it." At a time when many pressures are being placed on these fragile environments, such basic information is badly needed. Although there has been little attempt in this volume, and none apparently planned for the second volume, to analyze the various deserts of the world in an ecosystem context, the information provided should be invaluable when synthesis phases of the Desert Biome of the International Biological Program are reached.

The volume would probably be most valuable as a source book, since several topics are covered in great detail with complete bibliographies. For the reader with only a limited scientific background, some of the material may be rather difficult. However, several sections should be useful to the layman with an interest in deserts. The chapter on human adaptations to arid environments is an especially successful blend of technical and general information presented in a lucid and understandable manner.

The book is attractively packaged with excellent reproduction and few typographical errors. It would certainly be a valuable edition to the reference library of anyone interested in deserts.—*Rex D. Pieper,* Las Cruces. N. Mex.

ALSO WORTH NOTING

Establishment and Production of Grasses Under Semiarid Conditions in the Intermountain West by Harold L. Harris, A. E. Slinkard, and A. L. Hafenrichter, published as Idaho Agricultural Experiment Station Bulletin 532.

Brings together range seeding research conducted at Aberdeen, Ida., from 1947 to 1952. The study area, normally arid (8.79 average annual precipitation), received from 6.19 to 9.24 inches precipitation during years of study, which should make the results of the study of particular interest. The bulletin can be obtained from the Idaho Agricultural Experiment Station, University of Idaho, Moscow.

Sun, Soil, and Survival, An Introduction to Soils, by Kermit C. Berger, is an updated version of *Introductory Soils,* published in 1965. This revision opens with an ecological chapter, then covers the basic facts of plant nutrition. The author claims it is useful for interested farm people and gardeners, as well as for beginning students of soils in college and high school. This edition was published by the University of Oklahoma Press in 1972. 371 + vii p. $7.95. plants of British Columbia. Dominion of Canada Dep. Agr. Bull. No. 88, 44 p.

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