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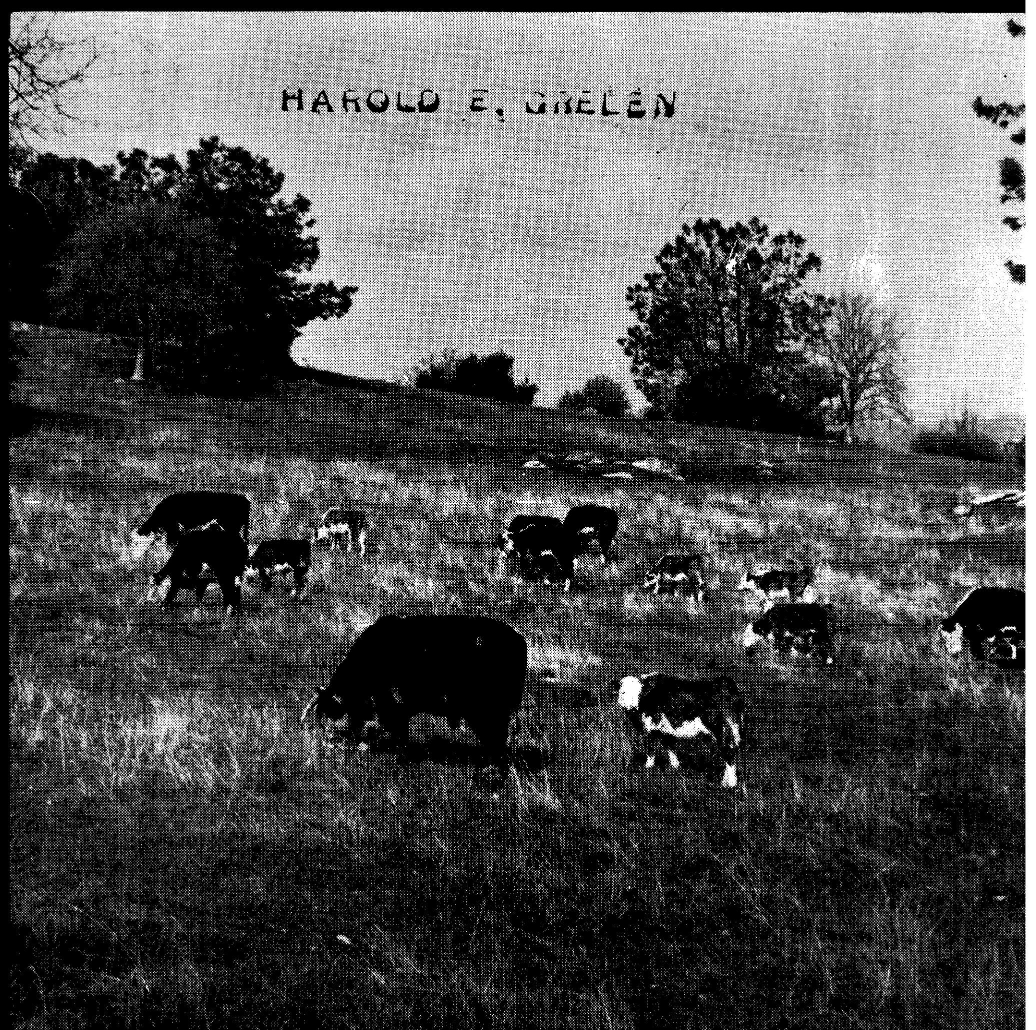

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Vol. XII, Nos. 1 and 6, January, November, 1959

Similar lists published heretofore are obsolete.

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Cover Photo — Home on California's Annual-Type Foothill Range

Photo by Jack N. Reppert, San Joaquin Experimental Range, March 1961

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Editorial

Wildlife and Range Biology—A Single Problem

A rancher calling upon a state or federal agency for help in solving his problems nowadays can seek specific advice from each of a wide variety of agricultural disciplines. Ranchers are learning to expect this refinement of service—indeed to depend on it. More than likely the specific advice will come from a specialist representing the particular discipline, and quite often several specialists will provide advice on a single general problem.

In advising the landowner, out of the valuable information and experience available from our various specialities, we too often seem to leave him with some uncertainty and confusion.

What can we do about it?

There probably are factors dealing, for example, with techniques of transmission of research data to landowners, with "salesmanship," or with interagency communication and cooperation which bear on my question, but I wish to discuss a different kind of factor: the influence of the concepts upon which agricultural practice is based.

I think a major cause for the confusion we may be generating at the management level is that behind any diversity among the recommendations we specialists are making there too often are very diverse concepts of the nature of the problems of land management.

Diversity among concepts admittedly is a potent force in the growth of knowledge. But we know that there is also an evolutionary force acting on these diverse concepts—a force which slowly refines them all until a few, most generally applicable ones, remain. Each of us would like our pet concepts to be among those few remaining which are "best." This desire need not make charlatans of us in the eyes of the practical man, however. We can teach him the way in which concepts develop. We can let him share the knowledge that all concepts do not have equal status in the chain of evolution toward the full reality. We can try to show him just where we think our particular concept stands in the evolutionary line before we ask him to follow a practice based upon it. I feel sure that the practical manager can learn to know that new concepts are not necessarily best just because they are original, or that concepts which have gone unchallenged for the longest time are not the most reliable just because they are the most venerable. The agricultural practitioner should be told that the best concepts for him probably are those which show a record of survival through the greatest number of well designed, carefully directed research challenges.

There is another way to deal with this problem of diversity among concepts. It is to attempt, through frequent review and criticism, to bring about a greater degree of order among them.

I therefore direct your attention to a few of the concepts about rangelands and wildlife which should, in my opinion, be marked for immediate revamping, or for elimination from use. I suggest this for two reasons:

(1) The first is that each of these concepts has, for a long time, exerted great influence on the outlook of research and management of rangelands and wildlife. Should any of them be seriously in error they will have contributed appreciable blindness or bias to our research and management efforts.

(2) The second reason is that each of the contemporary concepts I have in mind has achieved its present status not through much exposure to rigorous tests by the scientific method, but largely as a reflection of the history of human societies. Such concepts may serve to bind a society together, but they may

not be conservative or realistic about natural resources.

With which concepts am I dissatisfied?

First:—The concept that research in agriculture should be applied first to those aspects of biology for which an immediate or clearly forseeable economic implication can be seen—that pressing needs in land management are best met by initiating research at the points where the economic implications are most obvious. I call this the concept of treating symptoms, disregarding underlying biological processes.

The influence of this concept on research and management is sometimes minimized, possibly on the theory that if the worst symptoms can be relieved then there may be time for, and sufficient faith in, agricultural research to permit more fundamental studies. The situation need not be thus. American manufacturing, in the last 20 years, has demonstrated that fundamental, "abstract" research is much superior to "symptom treating" empiricism for producing usable knowledge.

Then there is the responsibility of the scientist for his science. If we really are to be biologists, we must study *biology*. The biology of rangelands is not just the pounds of beef per acre; it is the totality of biologic processes which make or prevent a desired yield. Biology is not just the control of unwanted plants, animals or insects; it is the biologic processes which provided for them in the first place, or which may replace them with other, possibly less desirable, ones later on. Biology is not just how many deer can live on one area as compared with another; it is also why the difference exists.

I have no quarrel with bio-economic studies. They are necessary for maximum refinement of land use. But these studies must be based on a sound biology. Successful range and wildlife management is a socio-economic problem, based on, and subsequent to, knowledge of the fundamental biologic process which characterize rangelands. Let us separate clearly the search for the fundamentals of the biology of rangelands from the treating of economic symptoms. Advancement of the biology of agriculture in the western world has too long followed the onset of pathological relationships between man and nature. We should be using our acumen primarily to prevent agricultural disasters—not just to cure them. Until the public which invests in range and wildlife research understands the necessity for this separation, we may be forced to continue with our symptom-treating approach. But, we must know biologic processes before we can utilize them. Let us tell our backers, the public, that this is so.

Second:—The concept that the biology of rangelands and the biology of wildlife are things separate and apart from each other.

This unnatural split has developed, it can easily be seen, because in the past at least two different segments of society have had separate interests in rangelands. The livestock producers worked to maximize livestock production, and wildlife, if recognized, was either an incidental pleasure or an irritating interloper on his rangeland resource. The sportsman, as a share holder in the public's wild game, demanded that the rancher give him access to that which is his, and at the same time held a fond vision of forests primeval in which to stalk his quarry.

Both sides are beginning to recognize the incompleteness of their separate viewpoints. Our rangelands are made up of, and depend just as much on, their native fauna as their native flora. Wildlife is an *inevitable* and *necessary component* of *rangelands*. Let us work to change the meaning of the word rangelands to the end that whenever the word is used, both its native flora and its fauna are always brought to mind. In the same vein, let us come to think of wildlife as a resource that is a product of its natural food supplies, its physical environment, and the history of its individual members. It is well to add here, also, that game animals are only a small part of the wildlife of rangelands. For every game species there are a dozen other native animals equally well established, equally influential and equally characteristic of the total biology of rangelands.

Third:—The concept that biological organisms are things of constant, unchangeable character, like physical forces such as heat, pressure or magnetism.

The totality of life and substance that is rangelands is a very complex, tightly interwoven matrix. This matrix has history—that is, the sum of previous events conditions and limits the course of future events. A clump of *Andropogon scoparius* does not exert the same influence on the surroundings—is not the same force—throughout its life. Clumps of it on one soil in the midst of the other kinds of plants are not exerting the same kind of force as clumps on another soil where this grass forms a continuous colony. A colony of cotton rats which has experienced years of existence in a stable, climax vegetation will not exert the same force on its surroundings as one which has endured violent fluctuations in food supply as a result of periodic overgrazing by cattle. We are too prone to expect that all members of a species of life, wherever found and whatever their history, are going to exert the same influence on, and be equally influenced by, their environment—that they are unchangeable forces. The life which comprises rangelands can be said to accumulate "experience," and its influence and susceptibility to influence are modified by this experience. By experience I mean here both the long term adaptive responses and the short term acclimatization responses of the organisms which form a rangeland matrix.

Ignorance of this vital characteristic has led us into an erroneous experimental practice. We expect that the characteristic behavior of an organism, or population of organisms, can be discovered by studying the form under the simplified conditions of an isolated laboratory experiment. Fortunately, for the progress of agricultural research, like organisms do seem to have some characteristics largely independent of their individual histories. However, we are now at the stage, if we are to progress, where we must recognize that the history of environmental influence is a critical part of the forces at work, and that taxonomically similar forms may have very different roles in the rangelands matrix if they have different histories.

This brings me to my conclusion, which is stated in the title.

The most realistic concept of the nature of rangeland is to consider it as a single, complex matrix in which the native fauna is as influential as the flora, the soils, and the physical environment. The most realistic way to study rangelands is to consider them as a complex so tightly interwoven that to remove any organism for study, or to control many of the organisms in order to study in place one or a few of them is to change the whole character of the system of forces involved.

My thesis, then, is let's face our problem—which is the study and management of a matrix of life. To understand it is to learn to study it as a matrix. The investing public will back us if they know what is required. Let's tell them.—Richard B. Davis, Dept. of Wildlife Management, A & M College of Texas, College Station.

Editorial

Suggestions for Solving Foreign Range Management Problems

During the summer of 1960 a formal seminar on range management problems of the world was held at Utah State University as part of a range management training program in cooperation with the Foreign Agricultural Service and the International Cooperation Administration. Participants from seven foreign countries reviewed the status of range management in their respective countries and made suggestions toward solving the major problems. The highlights of the discussion are reported here and I would like to give credit to the true authors of this paper: Mr. Rufino A. Sabado, Chief, Forest Grazing Section, Bureau of Forestry, the Philippines; Mr. Abdus Salam Swathi, Divisional Forest Officer, Sibi, West Pakistan; Mr. Jorge Brun, Range Management Specialist, National Institute of Research, Buenos Aires, Argentina; Mr. Jacob Katsir, Regional Soil Conservation Planner, Hakirya, TelAviv, Israel; Mr. Rasheed Abdel Magid and Mr. Hasim Abdel-Muttalib Mukhtar, Department of Animal Production, Omdurman, Sudan; Mr. Athanasious G. Chouliaras and Mr. George Koukouzelis, Agriculturists, Greece; Mr. Hasan-Namik Arkun, Assistant Director, Ministry of Agriculture, Ankara, Turkey; Mr. Mustafa Bedestenci, Range Management Specialist, Konya, Turkey; Mr. Ismail Hakki Akbay, Seed Increase Farm, Ankara, Turkey; Mr. Naim Dincer, Pasture and Forage Specialist, Eskisehir, Turkey; Mr. Urfi Guney, Veterinarian, Daracabey, Turkey; Mr. Muhlis Tan, Pasture Specialist, Eskisehir, Turkey; and Mr. Mithat Yener, Pasture Specialist, Adana, Turkey. The gentlemen listed above freely discussed the problens in their own countries and countries which they had visited. This paper is a compilation of the notes from the discussions.

As would be expected, many divergent problems were presented. Countries such as Argentina and the Sudan are faced with utilizing large expanses of relatively inaccessable rangelands while the more populated countries such as Israel are most interested in the intensive use of a limited land resource. Although geographical location, climate, population density, and local customs contribute to range management problems particular to each country, there are some problems that appear to be common to all countries represented in the seminar. The most common problem mentioned by all concerned was the lack of qualified personnel trained in range management. Although the ICA, United Nations, and other organizations send technicians to the countries, there are not enough to fill the needs. A common complaint of the foreign visitors was that the technicians sent to the countries often did not spend enough time in the countries to adequately learn the problems of range use and the customs of the people that helped to dictate the policies of land use in the respective countries. Likewise, foreign countries send technicans to this country for training, but many times the tour of duty is so short that it amounts only to an observational tour of problems here.

Representatives from the Sudan, the Philippines, Turkey, Greece, Argentina, and Pakistan listed the establishment of a range management curriculum in their home universities as the top priority problem in solving their range problems. The general feeling was that local technicians who had sound range management training could implement programs much more effectively than could foreign technicians. However, most representatives indicated that they would like to have foreign advisors who would work *in the field* with local technicians, since a man out of town is considered an expert the world over. At the present time Israel has a range management curriculum in the Hebrew University. They have some of their top ecologists and botanists in the United States at the present time obtaining advanced training in range management. Argentina offers courses in botany, ecology, and closely related fields, but does not have a range management curriculum in its universities. The Philippines has offered a course in forest grazing in its forestry college, but does not have a qualified teacher for such a course at the present time. In Turkey, Greece, and Pakistan training is available in botany, agronomy, and pasture management, but no courses are taught for the purpose of training people to work on native rangelands. The range management work in the Sudan is in the department of animal production and at the present time no range courses are taught. Without exception the foreign representatives felt that there was a great need for more range managers in their countries and that these technicians should be local technicians who understand the problems of the people. However, such local technicians are not available.

One of the solutions suggested by the group would include a three way approach to the problem: First, well qualified representatives from the foreign countries should continue to come to the United States for training. Second, technicians from the United States should continue to be sent to the foreign countries. If possible, these American technicians should be people whom a foreign representative has met and worked with during his stay in America. The foreign technician would take the responsibility of surveying the range problems in his country, organizing the information available, etc. before the arrival of the American technician. In this way, maximum use could be made of the American technician during the time he was in the country. By working together, both during the training period of the foreign representative in this country and throughout the American's visit to the other nation, close working relationships could be accomplished and many of the sociological problems of foreign aid could be minimized. Scientists from both countries could benefit from this international team approach. These two approaches to American aid to foreign countries could be accomplished by only minor modifications of existing policies.

The third method of American aid in establishing range management schools given a high priority by most participants, but it is considered here last because it is a major modification of present programs. The major suggestions were: First, send well qualified college teachers in closely related fields to this country for advanced degrees in range management. Second, upon return of the foreign representative to his home country send a well known range educator from this country to help him establish a curriculum in his country. Again, the team approach would add much to the establishment of a lasting program.

The second most common problem to all countries was the problem of making adequate surveys of the range resource. Of course this depends to a large extent upon the number of qualified range technicians available. In most cases labor is plentiful in foreign countries but the technician must have adequate training in sampling, vegetational analysis, statistics, and other principles to interpret the data and integrate the results into a meaningful management plan. Basic ecological data must be gathered and interpreted before useful surveys can be made. Use standards for each type of vegetation and each class of livestock remain to be established. These problems are not to be solved by a poorly trained range scientist. Certainly a large amount of the field data could be collected by short-course trained technicians; but if really meaningful range surveys and management plans are to be accomplished, then they must come from educated scientists, not trained technicans. The countries do not need, or want, large amounts of foreign scientists making their management plans. They are ready and willing to make their own applications if we will help educate them in the basic principles.

The third important common problem was the establishment of range research programs to give the managers sound bases for their management programs. Vast areas of research into use and management of tropical ranges are open in the Philippines and in the Sudan. Much investigation must be done in genetics, soils, plant-moisture relationships, and the application of basic research to the reclamation of arid regions if the depleted ranges of Mediterranean countries are to be made productive again. The problem of supplying the research projects with educated personnel must be met and once more we see that the key to solving range problems is the supplying of personnel.

Extension and acceptance of proven principles in range management is another problem common to all countries. Again, getting the known principles accepted is a job for individual workers to do and the people who can do it best are local people who are known and respected in their communities.

Another problem which occurs in some of the countries is the lack of exchange of current literature. Although ICA participants to this country are given membership in the American Society of Range Management as part of their assistance program, it may not be possible for them to maintain membership once they return to their countries. The exchange ratio between the American dollar and the currency in many foreign countries makes it almost prohibitive for a foreign technician to receive more than one American journal and many times even one cannot be justified on their low salaries. Most journals charge an increased rate for foreign subscriptions. Perhaps it would be more realistic to charge more for American members and give a reduction to foreign countries if we are actually interested in our material getting world wide distribution.

Although Argentina, the Sudan, and many other countries still have vast expanses of rangeland, other countries are feeling the demands of population growth more acutely. Intensification of production on the pastures and ranges are of paramount importance to the people of Greece, Israel, and Turkey. Here the ranges have been reduced to extremely low productivity following centuries of uncontrolled grazing. In many instances ranges have deteriorated to such a degree that it may be impossible to improve them by management alone. Large scale range revegetation or reclamation projects may be necessary to increase production. However, once the ranges are reclaimed, it will be necessary to develop management plans that will allow for continued sustained yield.

The Philippine livestock industry was all but destroyed during World War II, and it has been difficult to get pre-war ranchers to rebuild their herds since greater income may be obtained from investment in industry. Adequate markets must be developed for the produce in Turkey, the Sudan, and Pakistan if the livestock business is to reach the full potential in these countries. In some countries, such as the Sudan, cattle are considered a source of wealth and a man is not likely to reduce the item which adds to his prestige in the area.

Many of the range management problems of some countries are closely tied in with the customs and traditions of the people. For instance, in the Sudan and Pakistan nomadic grazing by tribal herds presents problems seldom encountered by other range managers. Regardless of the amount of technical training a range scientist who works in these countries has, he must be able to modify his training to fit the local situations. Other problems of local land use enter into the management of foreign ranges. The rancher in the Philippines is constantly plagued by landless squatters and trepass users of the range resource. Community pastures in Greece and Turkey may add to the problems of applying approved range practices to the lands. Therefore, the real progress in solving the range management problems in the countries will come from local people who have been trained in the principles of range management.

As it has been suggested, perhaps the best way to get the principles to other countries is by a team approach between individuals in the countries where range management is an accepted science and individuals in nations where scientific range management is unknown. Representatives of foreign countries appear to be eager to solve their own problems and given the proper educational facilities, they can solve them. It appears that education of foreign range technicians can be speeded up by establishing range management curricula in foreign universities, further exchange of technical personnel, and unlimited exchange of ideas and research.—Thadis W. Box, Range Management Department, Utah State University, Logan, Utah.

Continuous vs. Specialized Grazing Systems: A Review and Application to the California Annual Type

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Rotation of grazing among separate pastures was advocated as a range improvement practice before the turn of the century (Smith, 1895). Following intensive ecological studies in the Wallowa Mountains in Oregon, Sampson (1913, 1914) recommended that deferred-rotation grazing should be a general practice on national forests. Jardine (1915) and Jardine and Anderson (1919) presented the deferred-rotation scheme in diagram form. Numerous grazing experiments were conducted between 1920 and 1950 to test the value of grazing systems and much experience was gained in the application of rotated rest and grazing on range lands. Part of the experimentation showed that continuous grazing gave more animal production than various rotational systems and the conflicting results were briefly reviewed by Sampson (1951, 1952) and by Stoddart and Smith (1955).

Additional information is available from recent work in the United States and in range areas throughout the world. One objective of this paper is to analyze the facts and beliefs about grazing systems in an attempt to determine the reasons for conflicting results. The second objective is to propose the hypothesis that continuous grazing will give more animal production from the California annual type of vegetation than will rotational systems. This will be done by an interpretation of vegetational and animal data from several studies, a minimum field trial, and without a thorough experimental test.

Many people have unknowingly contributed to this report through most helpful oral discussions. Opinions about grazing systems have differed so widely that separate acknowledgement to each person would be inadvisable, besides I find impossible the listing of who said what. I graciously acknowledge the contribution by Mr. Donald T. Torell who helped greatly in the development of the hypothesis and who furnished the data from animals. Messrs. F. A. Branson, A. Heerwagen, and A. M. Schultz improved the manuscript with many worthwhile suggestions.

Definitions

Continuous grazing is used in this paper to include yearlong and seasonal grazing where animals are on a range unit for at least the whole of the growing period. Usually they graze a unit as long as the weather permits. The specialized systems include rotation, deferred, rest-rotation, and deferred-rotation grazing. Distinctions among these systems are easily made by definition (Stoddart and Smith, 1955) but are difficult in application. In practice, rotation and deferment are frequently combined to meet the operator's particular management problems. In experimentation, seldom have two different studies tested the same systems. Grazing and rest periods have been different in length, vegetational types are different in the various experiments, and the animals used have been of different kinds, ages, and sexes. Therefore, meaningful detailed comparisons of the specialized systems are all but impossible. On the other hand, continuous grazing has been compared with one to several of the specialized systems in numerous tests and that is the basis of this review.

Rotation grazing has been intensively studied on cultivated pastures, but that large body of information is used only to establish certain principles.

Advantages of Specialized Grazing Systems

The advantages of a specialized grazing program are generally stated in terms of improved range conditions. The rest from grazing allows the established plants to gain in vigor and to produce more seed. Seedling establishment is encouraged and palatable plants increase. The result is higher herbage yield. The establishment of a grazing system usually requires fencing of additional pastures so better livestock distribution and more uniform grazing are attained. These permit division of the herd and closer supervision. Since every pasture is grazed every year in most systems, it is argued that no forage is lost, that the mature plants are not damaged by grazing and that the animals scatter and cover the seed by trampling. Reseeding and brush control can be done on the rested pasture without interference from livestock. Damage in areas of livestock concentration will be eased. The improved range conditions are supposed to result in greater livestock production through more animals or more gains from the same number of animals.

The above list emphasizes vegetational improvement and control, livestock handling, and more livestock products. Improvement of deteriorated ranges is recommended as the principal use of specialized grazing systems. The kind of grazing system that maintains an excellent range and yields the greatest net return from excellent range is seldom mentioned.

Disadvantages of Specialized Grazing Systems

A specialized grazing system is difficult to establish on many ranges because sufficient water is unavailable and certain pastures must be used at the same season every year. Fencing costs are always high and are especially so on rough topography. Feed values are lost in the rested pastures because forage nutritive values decrease after plant maturity. Livestock production may not be increased enough to pay for the extra costs of developing water and fencing. Numerous experiments have indicated that specialized grazing systems may actually depress livestock gains when equivalent stocking rates to continuous grazing are maintained. No grazing may allow extreme fire hazards to develop. The disadvantages stress the additional costs and the lack of increased animal products to meet them.

Livestock Responses to Grazing Systems

The response of animals in experiments which compare continuous and specialized grazing systems has been varied but mostly in favor of continuous grazing. The experiments where no differences have been found include those in the northern Great Plains (Thomson, 1938; Black and Clark, 1942; Whitman, et al., 1943); in the southern Great Plains (Dickson, Fisher and Marion, 1948; Fisher and Marion, 1951; McIlvain and Savage, 1951); in forested summer range in eastern Oregon (Pacific Northwest For. and Range Expt. Sta., 1959); and in the southeastern United States in switch cane vegetation (Biswell and Foster, 1947; Biswell, 1951). Similar results have been reported from other countries. Among these are a 4-year study by Moore, et al. (1946) and Davies (1946) in Australia and a summary of 13 experiments that were conducted over a 17-year period in New Zealand (McMeekan, 1956). The latter reported that extreme differences in systems had small effect on animal production. After 8 years of work on five experiment stations in different vegetational types in Southern Rhodesia, continuous grazing was recommended as the most productive way to graze the natural vegetation (West, 1958).

In the northern Great Plains, Sarvis (1923) reported steer gains in favor of deferred-rotation grazing but after 25 years with the same experiment he reported moderate continuous grazing as superior (Sarvis, 1941). These results were restated in 1944 and in 1951 by Rogler. Significantly more livestock gains with continuous grazing were reported by Hyder and Sawyer (1951) for the sagebrush-grass type in eastern Oregon; by Smoliak after 9 years in the plains of southern Canada (1960); and by Suckling (1954) for unploughable hill land in northern New Zealand.

In addition to the 1923 paper by Sarvis, in which the results were later reversed the only report found that mentioned more favorable animal gains with deferred-rotation grazing was a 3-year study with lambs in Wyoming (Barnes, 1948).

The preponderance of evidence is that the system of grazing makes little difference in the production of livestock. Four studies showed advantage for continuous grazing and one for deferred-rotation. The results are in terms of animal weight gains and presumably equivalent stocking rates within each study. In view of the additional costs necessary to establish a special grazing system and to move the livestock, there seems little chance that a special system will be economically feasible. However, the picture is not that clear-cut. For example, it is a reasonable assumption that increased animal production will follow range improvement. The animal data must be interpreted in terms of vegetational changes in the same trials.

Vegetational Responses to Grazing Systems

The experiments which indicate either no advantage in livestock gains with specialized grazing systems or more gains with continuous grazing also report no significant differences in the vegetation under the various systems. For example, Moore, et al. (1946) in Australia found that sheep in different rotations did not change the composition of harding grass and subclover pastures. Smoliak (1960) described numerous vegetational changes during 9 years of cattle grazing on short grass ranges at Manyberries, Alberta, Canada and concluded that the total change was the same in the deferred-rotation and continuously grazed pastures. The Intermountain Forest and Range Experiment Station (1959) reported the same forage production in four grazing systems after 11 years on crested wheatgrass pastures near Benmore, Utah.

Several papers have presented vegetational data only and concluded that deferred-rotation grazing was superior to continuous. They include Hanson, Love, and Morris (1931) and Morris (1932) after 9 years of work in Colorado; Aldous (1938) and Anderson (1940) in an experiment started about 1919 in the bluestem type in Kansas; Canfield (1938, 1940) after 21 years of experience and experiments on black grama and tobosa grass in the Southwest; and Merrill (1954) after 4 years of work on the Edwards Plateau of Texas. The last study is still in progress and it includes measurement of animal responses. The Intermountain Forest and Range Experiment Station (1959) reports in a preliminary analysis of a 16-year study of spring grazing on sagebrush-grass range that rotational grazing permits heavier use than continuous grazing. They confuse the picture with data that the pastures used at different intensities within this study had similar herbage production at the end of the trial.

The value of specialized grazing systems for the restoration of depleted ranges has been emphasized by Clarke, Tisdale and Skoglund (1943) and Hubbard (1951) for short grass ranges in southern Canada and by Sarvis (1923, 1941) and Rogler (1951) in North Dakota. The work at Dubois, Idaho, (Intermountain Forest and Range Expt. Sta., 1959) mentions restoration. Frandsen (1950a, 1950b) recommended the deferred-rotation system as the easiest one to use to maintain range condition with bunch grasses, to reduce damage in areas where livestock naturally congregate, and to give protection during the establishment stage of other improvement practices.

Hormay (1955) has obtained remarkable improvement in range condition with a rest-rotation system in northeastern California. In this same study, Woolfolk (1960) shows that drought effects were minimized in a dry year by good management and that animal performance was best on the pasture grazed season-long. Reid and Pickford (1946) suggest fencing and deferred-rotation grazing for improvement of mountain meadows in eastern Oregon and eastern Washington. Observations with the once-over and twice-over systems in a mountain sheep allotment in Montana indicated that the once-over system was better because grazing was timed with forage development at different elevations, that less trampling damage occurred, and that the sheep were easier to manage. The range improved under both systems because of moderate use, open herding and 1-night bedgrounds (Heady, Clark, and Lommasson, 1947).

Although experiences such as these do not always give valid comparisons between systems, there is no doubt that improvements in range condition have been attained with grazing systems. How much improvement is due to the system of grazing and how much to other aspects of better overall management is not always clear. It is logical to believe that better ranges will increase animal production. The fact that many of the experiments did not show increased animal production may be because they were placed on good or excellent ranges or that range improvement occurred in all treatments. This indicates that other items such as stocking rate and distribution of animals are as important or even more important than the grazing system. On the other hand, the use of a specialized system as a part of a better management program is an important consideration.

Factors Influencing the Results

One finds evidence in these experiments to support either contention that continuous grazing or a specialized system is best. Of more importance than defense of one system or another is to understand the operation of the factors which influence the results. Such factors include stocking rate, relative resistance of plants to grazing at different seasons, uniformity of pastures, frequency of grazing, time between deferment periods, emergencies in managing livestock, weather, vegetational differences from one area to another, topography, and unrecognized conditions. Few specific data are available on these points. Experiments that determine the effects of these factors singly and in combination are extremely expensive. A full understanding will be difficult to attain.

Some authors have suggested reasons why their experiments failed to show an advantage for the specialized system. Anderson (1940) mentioned that livestock were moved at the wrong dates. Black, et al. (1937) wrote that the same stocking rate on pastures of different grazing capacities influenced the results. Hubbard (1951) and Hyder and Sawyer (1951) believed that heavy use in the spring grazed pasture in one year out of three caused more damage than was repaired by rest from spring grazing in the other two years.

Stocking rate is frequently discussed as an important factor determining the outcome of grazing trials and two or more rates have been included in part of the experiments. The range of results is illustrated as follows: The Pacific Northwest Forest and Range Experiment Station (1959) found no interaction between system of grazing and stocking rate; another found no difference in systems at heavy stocking rates but an advantage for deferred-rotation at moderate rates (Clarke, Tisdale, and Skoglund, 1943); a third mentions that climate is more important in causing fluctuations in production than intensities of grazing at light and moderate rates (Intermountain Forest and Range Expt. Sta., 1959); and a fourth indicated that stocking rate was the most important factor in determining the results of grazing trials (McMeekan, 1956). Few, if any, studies have included adequate measurements and controls of all the variables so that the main effects of system of grazing could be determined.

The relative resistance of plants to grazing at different seasons has been studied by subjecting them to different clipping frequencies. This information is used to suggest the periods of rest and grazing. But grazing on range land is neither as severe nor as sudden and it is more selective than clipping treatments. If the period between clippings is short, the implication is that all the herbage is consumed at near the same rate that it is grown. A constant adjustment of grazing pressure is required to accomplish this—a condition which is possible in a single pasture but next to impossible on a ranch basis. If the period between clippings is long, lengthy rest periods and short grazing periods are implied. This requires large groups of animals or a large number of pastures and animals moved frequently—again conditions of questionable practicality on ranges. Clipping treatments, except those on pure stands ignore the selectivity factor which is important to animal health and to range condition. A review of the large body of information on the effects of clipping is not needed to make the point that plant response to clipping is not the same as response to grazing on a ranch basis.

Certain characteristics of range herbage and animal production influence the results obtained by different grazing systems. Range animals are run for the most part on a long-time basis and they must receive about the same amount of feed every day with slight changes due to weather, pregnancy, fattening, etc. The demand for feed on a ranch varies somewhat during a year. As young animals grow, demand gradually increases and there is a sudden decease in demand when animals are sold. Thus, a cycle of high and low demand exists on most ranches.

A second cycle is present in the herbage supply. Herbage increments are small at the beginning of growth, increase rapidly in the short flush growth period to a peak at plant maturity, and then cease. During a dry period there is a decrease in herbage by shattering, insects, rodents and other causes not controllable by the manager. Grazing continues so there is a gradual decrease in available feed. In contrast to cultivated pastures where a considerable control of the cycle can be exerted with fertilization, irrigation, mowing, and choice of species, the herbage supply cycle in range vegetation is largely determined by factors beyond the operator's control. Certain exceptions exist where range fertilization and seeding can be done economically.

When the cycles of demand and supply are superimposed, four periods are evident: (1) Consumption of forage is more than the green increment in the early growing period and animals must eat old or conserved forages along with the green. (2) Consumption and increment are equal. This is a very short period on range land and may be no longer than a day or a week. (3) Increment exceeds the demand for a short period during the time of flush growth. (4) A dry period without forage increment but with continuing demand on the increment unused in period 3.

Probably the very highest livestock production would come with adjusting stocking rate to herbage growth so that all allowable forage is used by the end of the green season. The forage would be used when it is most palatable and when it has the highest nutritive content. But, as mentioned earlier, this is impossible with relatively constant stocking in a year-long ranch operation. Therefore, grazing use tends to reduce the supply of forage in all but period 3.

Specialized systems concentrate animals so that some pastures get eaten down. If this is in period one, the new growth is rapidly diminished and the capacity of the plants to recuperate is endangered. The second period is too short and elusive of determination on range lands to permit consideration in the grazing program. The third period gives more than adequate forage so the system of grazing probably makes little difference to either plant vigor or animal production unless animals are concentrated to a degree that prevents plant development. Unfavorable grazing consequences are minimized in the fourth period because the above ground plant parts are mature.

Specialized grazing systems on range lands tend to be rotations in growing period grazings where decreases of forage in the grazed pastures are counter-balanced by increases in the rested pastures. The problem is to prevent overuse on the grazed pastures during the first period. Where overuse occurs, even for a few days, livestock gains will be lowered. Herein may lie a reason for lower gains with specialized grazing systems than with continuous grazing in some of the experiments.

Of interest is a point made by Willoughby (1958, 1959) that whenever there was less than 1,400 pounds per acre of herbage on the ground sheep were not gaining at their maximum rate. He found this to be an asymptotic relationship with increasing availability above zero on the one hand and increasing quality on the other resulting in increasing animal production to a maximum imposed by the animals. If there was always 1,400 pounds per acre available, the animals gained at their maximum rate regardless of the actual amount of forage or the grazing system. As it seems more likely that available forage is below this limit when animals are congregated in a rotation system than when they are allowed continuous use, especially in period one, herein may lie another explanation of less animal products from deferred-rotation grazing than with continuous grazing in many experiments.

The figure of 1,400 pounds is unimportant to this discussion. The important point is that a relationship exists between the amount of feed available and animal performance. Many factors of animal type, age, weight condition, and health; and pasture type, quality, species, etc. will change the actual values of the asymptotic curve. These are still largely unknown and the form of the relationship needs to be determined for various combinations of factors. Of interest is that other workers (Johnstone-Wallace and Kennedy, 1944) arrived at a similarly shaped curve with an asymptote near 1,000 pounds per acre for dairy cows.

In grazing experiments, factors which are primarily vegetational or primarily animal or both may be limiting. If pastures are not limiting, as with light or moderate stocking rates, the capacity of the animals limits production. Under such conditions, no matter what the pasture treatment, animal responses reflect their ability only. On the other hand the pastures must be limiting the capacity of the animals to produce if the animals are to give a valid measure of pasture differences. It would seem that heavy stocking rates and high producing animals would be more likely to show differences in grazing systems than low or moderate stocking rates and low producing animals. Many experiments have been intentionally started with an effort to achieve moderate stocking. Results from them can give little more than animal differences.

What System for a California Annual Range?

In the absence of a thorough study of grazing systems in the California annual type the question of which one would give most efficient production must be answered on a basis of related information. The arguments presented above indicate that continuous grazing should be the choice. Results from several ecological and grazing experiments presented below substantiate that conclusion. The studies were concerned with description of vegetation as it changed under the influence of weather, grazing and other treatments. The range manager can manipulate some aspects of the California annual vegetation but over others he has little control. Most of the work was conducted on the Hopland Field Station of the University of California. The Station is located in the coastal mountains about 100 miles north of San Francisco and 40 miles inland

The California Annual Type

The annual plants germinate in the fall with the first rains, grow slowly until about the first of April, grow rapidly for six weeks and are usually mature and dry by June first. Changes in relative and absolute amounts of the different forage species are to a large extent correlated with weather fluctuations.

The annual type is a complex one composed of many species. For example, in one study area that was 100 feet square, about 50 species were found. Annuals make up at least 97 percent of the foliage cover and 80 percent or more of the species are introduced from the borders of the Mediterranean.

Fluctuations in Species Composition

The proportion of the different species that comprise the annual vegetation varies to such extent that some years are known as good clover years, some as filaree (*Erodium botrys*) years, and some as grass years. The magnitude of these differences is shown by data from a series of plots which were sampled from 1953 to 1960 (Table 1). Grasses constituted 87 percent of the cover in 1958 but only 22 percent in 1960. Filaree varied between 6 and 45 percent and legumes from 1 to 17 percent. Rainfall was heavy at Hopland in 1958 (60.4 inches) and well distributed throughout the growing season. In 1960 rainfall was 28 inches and there were two dry periods, one of 94 days, which greatly favored the filaree. Extensive vegetational differences which are largely beyond the control of the land manager result from the various weather pattern in the California annual type.

Fluctuations in Time of Maturity of Major Species

The period of rapid plant growth in the spring is one of a progression of different species (Heady, 1958). Observations at Hopland indicate that desirable and undesirable species mature throughout the season. Legumes (*Trifolium* spp., *Lotus* spp., *Lupinus* spp.) and undesirable weeds (*Agoseris heterophylla, Baeria chrysostoma, Hypochoeris*

Table 1. Percentage species composition based on herbage cover in 64 ungrazed plots at the end of the growing season, 1953-1960.

	1953	1954	1955	1956	1957	1958	1959	1960
Bromus mollis	11.5	14.1	10.5	15.0	14.2	21.2	17.1	4.6
Other grasses	36.3	44.7	18.4	26.0	23.0	65.9	37.6	17.8
Legumes	6.1	2.6	16.8	6.1	5.0	0.9	2.1	12.7
Erodium botrys	20.1	18.7	34.7	31.5	26.2	6.1	29.4	44.9
Other broad-leaved plants	26.0	19.9	19.6	21.4	31.6	5.9	13.8	20.0

glabra, Orthocarpus, etc.) seed early and at the same time. Little quaking grass *(Briza minor)* and silver hairgrass *(Aira caryophyllea)* mature early, the fescues *(Festuca* spp.) intermediate, and soft chess *(Bromus mollis)* and ripgut *(Bromus rigidus)* mature near the end of the season and slightly later than bur clover *(Medicago hispida)*. Filaree and wildoat *(Avena barbata)* set seed all spring. The last plants to mature are mostly undesirables; medusa head *(Elymus caput-medusae)*, nit grass *(Gastridium ventricosum)*, tarweed *(Madia* spp.), turkey mullein *(Eremocarpus setigerus)*, and prairie three-awn *(Aristida oligantha)*. These relative times of flush growth and maturity for the many species are within a two-month period, except for the summer species. A certain amount of telescoping in response to weather is evident in years with low spring precipitation. In 1956 all the species set seed and turned dry in a 3-week period. Two points are important; the short and variable time when species mature, and desirable and undesirable species mature both early and late.

Unless the grazing pressure is extremely heavy, sufficient seed will be produced for the next crop and rest from grazing during the fast growth period is not needed. Pechanec and Stewart (1949) have shown the same relationship for the annual cheatgrass ranges in southern Idaho.

Fluctuations in Herbage Production

Weight of herbage production at the end of the growing season may differ over 100 percent between years (Table 2). From 1954 through 1960 production varied from less than 1,000 pounds per acre to about 2,000 pounds in one set of plots on the Hopland Field Station. Although the amount of production may be different for other areas, yearly differences of similar magnitude have been reported by Talbot, Biswell, and Hormay (1939) and Bentley and Talbot (1951).

The amount of green herbage available during the winter wet period may be almost nil in some years and abundant in others. In a six-year period, 1955-1960, the herbage varied from about 200 pounds to over 1300 pounds per acre on March 1 in ungrazed conditions. Small amounts of winter forage can be expected in the years with late or scanty fall rains and low temperatures.

Fluctuations in Nutritive Content of Annual Herbage

Young herbage has a high moisture content which reduces its value as livestock feed. Not many data are available but percentages between 70 and 87 have been reported by Gordon and Sampson (1939); Luick, Torell, and Siri (1959); and Torell (1954). The first authors report

Table 2. Average oven-dry weight of herbage in grams per square foot on 63 ungrazed areas in a 200-acre pasture, 1954-1960.

	March	June
1954	......	18.41
1955	6.24	9.66
1956	2.33	12.86
1957	3.29	15.67
1958	12.31	19.01
1959	3.31	13.79
1960	2.25	7.77

moisture contents of 62 to 86 percent for plants in the flowering stage. Moisture content in herbage is high immediately after a rain and in the morning. It decreases during the day and with increasing days after a rain.

A decrease in percentage of crude protein and an increase in crude fiber with advancing stage of plant maturity are well established relationships (Gordon and Sampson, 1939; Hart, Guilbert, and Goss, 1932). It is also commonly known that rains on mature herbage leach the nutrients and the result is poor feed with crude protein contents less than 5 percent.

If a mature sheep requires 4 pounds of dry matter per day, then it must eat 20 pounds of green material at 80 percent moisture, nearly 27 pounds at 85 percent moisture, and 40 pounds at 90 percent moisture. Although data are not available, animals are likely to be improperly nourished during periods of wet weather when the forage is young because the high moisture content in the feed prevents them from consuming enough bulk to get the daily requirements of total digestible nutrients. In the dry season sufficient bulk will be consumed but it may not contain adequate nutrients.

Fluctuations Related to Site

Maturity of the annual plants occurs over the whole ranch in the California annual type during a relatively short period. The elevational range is usually less than 3,000 feet and does not influence the speed of maturity as much as local soil conditions. Some soils are deep while others are shallow. On deep moist soil in the swales vegetation stays green longer than that on the hillsides where the soils are often shallow. North slopes stay green longer than south slopes. Thus, soil and moisture conditions result in more seasonal variation in plant maturity than elevation on most ranches. Fencing the range sites separately is seldom practical and every pasture will include areas with different forage potentials. Management of livestock on a basis of sites is difficult.

Influence of Degree of Use on Annual Vegetation

Too light utilization results in an increase of the tall annual grasses and less filaree and clover. Close grazing delays fall growth and reduces winter growth of the annual forage plants (Bentley and Talbot, 1951).

A study of the effects of mulch on the composition and production of annual vegetation has been conducted since 1952 (Heady, 1956). After removing the yearly changes due to weather by experimental design, the proportions of the different species were shown to be a function of the amount of mulch on the ground when the growing season begins (Table 3). Mulch is here defined as the total dry plant material above the soil surface regardless of its position or state of decomposition. With amounts of mulch in excess of about 700 pounds per acre the tallest grasses such as soft chess and ripgut were favored. With no mulch at all the vegetation was composed of small, unpalatable broadleaved plants such as *Baeria chrysostoma*, *Hypochoeris glabra*, *Orthocarpus erianthus*, and many others. Grasses of low forage value such as little quaking grass and silver hairgrass were associated with small amounts of mulch and others like the annual fescues and nit grass with intermediate amounts. More grass resulted in fewer legumes. Filaree did well regardless of the mulch.

Table 3. Percentage species composition in 1952 and two years later as a result of removing and leaving all dry plant material on the ground.

	All mulch removed		All mulch left in place	
	1952	1954	1952	1954
Bromus mollis	0.9	1.9	2.7	37.3
Other grasses	43.6	47.4	36.4	31.3
Legumes	6.8	2.8	12.7	1.5
Erodium botrys	14.5	22.3	22.7	17.0
Other broad-leaved plants	34.2	25.6	25.5	12.9
	100.0	100.0	100.0	100.0

Not only did manipulation of mulch change the composition but it also changed the herbage production (Table 4). Roughly twice as much herbage was produced with all the plant-material left in place than when all was removed. Intermediate amounts of mulch resulted in intermediate herbage production. The study suggests that mulch or dry plant material standing upright is more effective than the same amount lying on the soil surface. These results indicate that degree of herbage removal, or degree of utilization, is an important factor in determining the characteristics of the next crop, within the limits set by weather. Also it would seem wise to leave the least nutritious plant material as mulch and to encourage as much animal selectivity of the better plant parts as possible. Animals should be widely spread and allowed to graze for long periods to accomplish these conditions most efficiently.

Influence of Seasonal Use on Annual Vegetation

Almost no data are available on the effect of season of use in the annual type when other factors such as stocking rate and improvement practices are held constant. Significant differences in total production and species composition at the end of the growing season due to seasonal grazing by sheep or deer are not apparent in the studies at the Hopland Field Station. It stands to reason that heavy use early in the season will change the composition and much data are available on this point with seeded grasses and legumes (Love, 1944; Jones and Love, 1945; Love, 1952; Williams, Love, and Conrad, 1956). A commonly heard suggestion is to concentrate grazing animals in the early spring to discourage the undesirable annuals and to encourage the more desirable species. This is true where the desirable species are seeded legumes and perennial grasses and the undesirable species are the resident annuals. However, within the annual type the desirable and undesirable species mature throughout the spring season and grazing to reduce one group and to favor the other on a permanent basis is difficult.

Table 4. Average oven-dry weight of herbage in grams per square foot resulting from mulch manipulation.

	All mulch removed	All mulch left in place
1954	11.31	25.99
1955	11.85	21.39
1956	7.94	16.43
1957	18.00	29.63
1958	11.53	33.78
1959	8.22	20.76
1960	17.94	42.45

Speed of Vegetational Changes

Response of the annual vegetation to manipulation and to weather patterns is very rapid. The major responses of vegetation to mulch manipulation were attained in a year or two and maintained by continued treatment. Additional evidence of rapid response is available from a study of burning in the annual grass type (Hervey, 1949). The resulting vegetation due to various treatments is permanent only so long as the treatments continue. For example, by a combination of mulch manipula-

Table 5. Percentage species composition at end of the first and second growing seasons after seeding and mulch manipulation.

Plot	Species	July 9, 1957	June 3, 1958
Soft chess broadcast seeded and half of mulch removed	*Bromus mollis*	35.0	76.0
	Erodium botrys	48.0	7.0
	Medicago hispida	6.5	2.5
	Bromus rigidus	2.5	12.0
Filaree seeded and all mulch removed	*Bromus mollis*	24.8	79.0
	Erodium botrys	52.5	6.0
	Medicago hispida	4.2	2.5
	Bromus rigidus	3.0	9.0
Bur clover seeded and half of mulch removed	*Bromus mollis*	32.0	85.5
	Erodium botrys	35.7	2.0
	Medicago hispida	16.3	0
	Bromus rigidus	3.5	7.0
Resident annual no mulch removed	*Bromus mollis*	43.8	85.0
	Erodium botrys	39.3	4.5
	Medicago hispida	2.5	0
	Bromus rigidus	10.2	9.5

tion and seeding, four plots were obtained with percentages of soft chess between 25 and 44, filaree between 36 and 52, and bur clover between 2.5 and 16 (Table 5). These plots were left ungrazed and untreated. The next year, soft chess percentages were between 76 and 85, filaree between 2 and 7 and bur clover from zero to 2.5 percent. There seems little doubt that composition of the annual type can be changed, but the results are temporary and last only as long as the particular intensity and pattern of treatment, or grazing, are maintained. The over-riding influence of annual weather in causing vegetational changes on annual ranges is illustrated. Systems of grazing which give pastures a growing season rest every three or four years in order to allow range improvement would seem to be ineffective on annual ranges because any gain in one year can be wiped out the next by weather alone.

Grazing Habits of Sheep

The fact that animals prefer different forages at different times of the year and that they select different forages in relation to the amount available is well known. In a study of grazing preference, as determined by sheep with esophageal fistulas (Heady and Torell, 1958), results indicate that the animals avoided bur clover in the winter, ate it in large amounts in May and ate stems and burs in July. Grass appeared in the sheep's diet in the winter in greater proportion than it occurred on the ground. Filaree composed a high proportion of the diet when the animals were on dry forage even though that plant was shorter than the grasses, and many of the leaves had shattered. Much of the filaree eaten in July was fruits (Table 6). Various plants and plant parts, therefore, are selected at different times of the year.

If livestock are congregated, the palatable species get heavy use while the same species in rested pastures are unused. The same may be true for the less palatable species and the result is uniform grazing. Even grazing is often given as a desirable condition that is easily obtained by concentrating animals in a pasture and rotating the use among pastures. There is a difference of opinion on this point for range grazing. One suggestion is that the animals should be given free choice of as large an area as possible when the feed values are high. No access to plants with a high value for a short period is a loss of forage. Potential gains cannot be made up later when the feed values are low (Sarvis, 1941; McIlvain and Savage, 1951; Rogler, 1951).

Sheep select material of high nutritive value (Weir and Torell 1958). Chemical composition of material collected by fistulas was universally higher in crude protein and lower in crude fiber than material collected by clipping plots (Figures 1 and 2). These preliminary data indicate that sheep will select plants and parts of plants which are higher in nutritive value than the average of the herbage available to them. The opportunity for the selection of high quality feed is especially important during the dry season when feed values are low.

Digestive upsets have been observed in animals on the Hopland Station when they were shifted to ungrazed forage during the growing season. This may be due to the shift from a feed high in coarse material to one high in leaves, or from one low in crude protein to one with a higher protein content (Torell and Weir, 1959), or from one low to one high in total digestible nu-

Table 6. Percentage of three species in herbage available to sheep with esophageal fistulas and the percentage in the diet at five different dates in 1957.

Date	In herbage	In diet
Bromus mollis		
Feb. 1	41.3	56.5
Mar. 5	47.1	47.4
Apr. 1	42.5	52.9
May 2	48.0	37.5
July 9	48.2	11.2
Erodium botrys		
Feb. 1	38.2	38.0
Mar. 5	39.9	45.6
Apr. 1	36.2	36.3
May 2	37.5	28.2
July 9	35.9	76.1
Medicago hispida		
Feb. 1	9.6	2.0
Mar. 5	8.0	4.2
Apr. 1	13.1	10.6
May 2	9.1	34.4
July 9	6.0	11.4

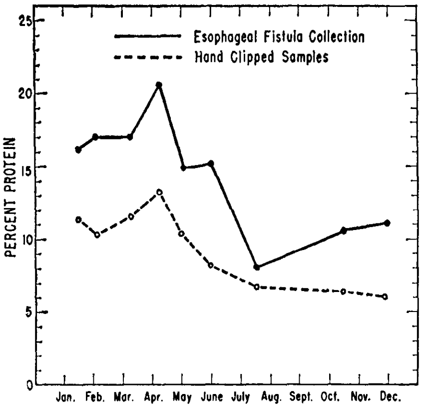

FIGURE 1. Percent protein in forage collected by sheep with esophageal fistulas and by hand clipping of square foot plots at different times (graph furnished by D. T. Torell).

trients. When animals are moved suddenly from one feed to another in a fattening operation, digestive upsets often occur. These have been attributed to the sudden change in nutrition. Therefore it is reasonable to suspect that digestive upsets apparent after sheep have been moved from one pasture to another are also due to change in nutrition.

Two recent papers (Brundage, 1960; Blaser, et al. 1960) show that the digestibility of pasture herbage increased for the first day or two when animals entered a fresh pasture and declined as the supply of available herbage diminished toward the end of the grazing period. Digestibility values were positively correlated with the degree of selective grazing in a repeating cycle that correspond to the rotation pattern. Milk production also exhibited similar cyclic fluctuations (Brundage, 1960; Kennedy, et al. 1960).

In moving a large band of ewes and lambs from one pasture to another, lambs have been observed to become separated from their mothers and, thereby, weaned prematurely. This happens most frequently when the sheep are driven a considerable distance between pastures. South Dakota (1958) reported that, "when ewes are moved frequently under a rotation system, the disturbance of their routine may also have an effect on their production."

The available information on the effects of moving animals on selectivity of forage by animals and on forage digestibility indicates that changing animals from one pasture to another upsets their normal physiological processes. This may not be serious in terms of animal production if sufficient high quality feed is always available. On the other hand if they are forced to eat herbages of low value near the end of each rotation period, it will lower their production. Rotation grazing congregates animals and frequently forces them to eat less nutritive materials than are available in ungrazed pastures.

One Test of Continuous vs. Deferred-Rotation Grazing

Since 1955 two 40-acre pastures on the Hopland Field Station have been used to test the effects of continuous and deferred-rotation grazing on the vegetation and animals. Both pastures have been essentially without deer and the same sheep have been in the pastures for the five years. They have lambed on the range and grazed without supplements since 1956. One pasture is divided into three parts.

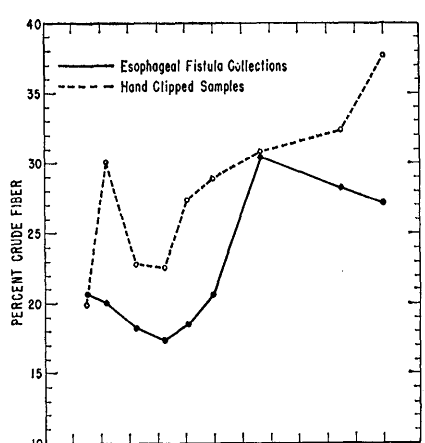

FIGURE 2. Percent crude fiber in forage collected by sheep with esophageal fistulas and by hand clipping of square foot plots at different times (graph furnished by D. T. Torell).

One division is grazed in the early part of the growing season, one in the middle, and the third near the end of the growing season. These have been rotated on a yearly basis so that each division is grazed at each time once in three years. The sheep are allowed free access to all three divisions during the dry season. The other pasture is without divisions.

The vegetation has not shown different trends in species composition, density, and herbage production under the two treatments. Differences between years have completely masked any differences due to grazing system. The average weaning weight of lambs has been consistently higher in the pasture with continuous yearlong grazing (Table 7). These are preliminary results because the experiment is still in operation. The treatments have been reversed to determine the influence of inherent pasture differences upon the results.

Table 7. Average 120-day weight of single lambs under two systems of grazing (data collected by D. T. Torell).

	Continuous grazing	Deferred-rotation grazing
	— — (Pounds)	— —
1956	78.6	74.1
1957	80.9	70.9
1958	81.0	72.4
1959	74.4	62.9
1960	77.1	74.6

Discussion and Summary

The results of experimentation with grazing systems, such as continuous and the more specialized systems (rotation and deferred-rotation), are reviewed. None of these experiments have been comparable because they have employed different combinations of grazing and rest periods; they have been conducted on different types of vegetation; and they have used different kinds and combinations of animals. Continuous grazing has commonly been one of the treatments. For this review emphasis is given to the comparison of continuous grazing with other systems.

Weight gains of livestock have generally shown no difference due to grazing system or more gains have been obtained with continuous grazing. Changes in vegetation in those experiments reporting livestock responses have shown little differential effect of grazing system on range condition. When improvement or deterioration has occurred, it has been generally the same in all treatments.

On the other hand, there have been numerous reports where range improvement has been obtained with a specialized grazing system. These are largely based on application of grazing systems on range units and ranches. They pose a question of why, for example, does deferred-rotation grazing show significant results in the management of land while it has not been proved superior under experimental test? The answer probably lies in other features of management. When a rancher begins a deferred-rotation system, he usually changes the stocking rate, improves the distribution of animals, controls brush, reseeds, etc. In experiments these factors are held constant. The difference in results between grazing experiments and general application may be due to these practices and not to the grazing system.

Several authors have mentioned that the primary value of a specialized grazing system is in the restoration of depleted ranges. However, many of the experiments were started on ranges in good or excellent condition, where the restoration aspect has little chance to become evident. Practical application frequently begins with deteriorated ranges where range improvement can be evident immediately. How much improvement can be attributed to the system of grazing and how much to change in the other management practices is unknown.

An evaluation of this evidence indicates two major conclusions. One is that a specialized grazing system has no advantage in livestock production over continuous grazing, at least with good or excellent ranges under comparable stocking rates and degree of care in other management practices. The second is that other management factors are more important in the production of livestock than system of grazing. Evidence in support of these conclusions has been reviewed in the paper and is briefly summarized below along with some suggestions for conducting tests of grazing systems.

When the demand cycle for forage on a ranch basis is superimposed on the supply cycle of herbage growth, it is evident that during the relatively short period of rapid growth preceding plant maturity, herbage is growing faster than it is consumed. Except for that period the more animals are concentrated, as with rotation systems, the more some pastures get eaten down. A positive correlation exists between the amount and quality of forage available and animal performance below a certain level. Rotation systems are designed to force animals to graze closely before they are moved to fresh feed. This cycling of available feed from large amounts to very little through a grazing period materially affects the diet. Studies on animal preference for plant species and parts of plants in the California annual type and digestibility studies elsewhere are cited as evidence on this point.

A positive correlation exists among the degree of forage selectivity by livestock, the dry matter intake, and the quality of feed consumed. Selectivity decreases with an increase in stocking rate and an increase in proportion of herbage removed from a pasture. In the comparison of grazing systems, animal output is often confounded with stocking rate and the concurrent effects of differential selective grazing. Even though two pastures of the same size are grazed with the same number of animals, stocking rates and selectivity are not constant unless herbage production is also constant from day to day and between pastures. Since animal output is correlated with dry matter intake and quality of feed consumed, it is also correlated with the animal's opportunity to select forage. This suggests that for grazing pressures to be equal on two pastures the degree of selectivity, amount of dry matter intake, and quality of feed consumed should also be equal. Given animals with the same productive capacity, they should give equal response under these conditions. To equalize grazing pressure in different pastures, the stocking rates should be adjusted under one system of grazing until the animals give the same production at a level below their inherent capacity. This is suggested as the procedure to calibrate the pastures before different grazing treatments are tested.

In order to measure different pasture treatments the stocking rates should be simultaneously and equally increased until production is reduced to a greater degree on one treatment than another. Such a procedure eliminates the inherent productive capacity of the animals from determining the pasture results. The fact that different pastures have different numbers of animals and that all pastures are heavily used should cause no concern in experimentation.

Specifically for the California annual type, production fluctuates widely in terms of total amount, season of growth, species composition, time of maturity, moisture content, nutrient content, and on different habitats. The major causes for these fluctuations are weather and soil. Evidence was presented that the degree of use is an important grazing factor causing vegetational change and that it is superimposed on natural fluctuations. Changes in the California annual type are rapid and the over-riding influence of annual climate in causing these changes was emphasized.

With rotation systems the usual objective is to force the animals to consume all or most of the available forage in a short time. The fallacy of this system in terms of livestock responses is evident in the work which indicates that animal production decreases with a decrease in quantity and quality of feed available and degree of forage selectivity. On the other hand yearlong grazing allows the animals to choose the feed they prefer. Under ranch conditions in the California annual type ample amounts of feed are more likely available in the winter season with the animals widely scattered than when they are bunched. In the deferred-rotation system the objective is often to graze at a time or to a degree that will favor certain plants but not others. In the California annual type the changes are so rapid that any improvement to one pasture is lost before the cycle of a deferred-rotation system can be repeated.

Yearlong grazing at reasonable stocking rates, is the best way to manage the California annual type because it pays primary attention to the day by day animal needs and because yearlong grazing amounts to a partial deferment every year. Enough forage must remain at the end of the forage growth period so that the animals have ample feed to last them until the new crop is produced several months later. This amounts to a very light grazing on all the range during the growing season every year. At the same time, it should be realized that animals must be congregated occasionally for purposes of protecting new range developments and for certain animal husbandry practices. These do not destroy the hypothesis that continuous grazing should be practiced on the California annual type.

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Emergence and Growth of Annual and Perennial Grasses and Forbs in Soils Altered by Halogeton Leachate[1]

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Competition, as it influences plant distribution, is an integral part of community ecology. However, competition for factors of the environment is not the only effect one plant has upon another. Some plants, for instance, chemically alter the environment, usually the soil, so that many species of plants cannot become established, or if they are present, growth is impaired.

Several workers have found growth-inhibiting substances in various plants. Muller (1953) extracted growth-inhibitors from *Franseria dumosa* and *Encelia farinosa*. The former plant harbors shrub-dependent herbs while the latter does not normally do so. Muller suggests that *Franseria* creates an environment where microflora can flourish and destroy the toxin. Toxic organic substances have been found in other plants (Bonner and Galston, 1944; Gray and Bonner, 1948; Kommedahl *et al.*, 1958, 1959; Bennet and Bonner, 1953; Woods, 1960; and Nord and Van Atta, 1960).

Bonner (1950) stated that association or non-association of different species is, in some instances, the result of specific chemical compounds secreted by one of them. Muller (1953), however, concluded that inhibiting organic toxins are ineffective in nature presumably because they are broken down by soil microflora or absorbed by soil colloids and are not accumulated.

Inorganic substances, such as salts, would not be broken down by microflora but may concentrate in sufficient quantities to inhibit growth. The influence of inorganic substances on inhibition of germination and growth has received considerable attention in the field of irrigated crops but little study in the salt-desert-shrub vegetation type. Gates *et al.* (1956) suggest that inhibiting substances could be functional in the maintenance of pure stands of various species on the salt-deserts of Utah. Others have found that extracts of halogeton residues impaired germination and growth of plants (Smith and Rauchfuss, 1958; and Haas, 1957). Eckert and Kinsinger (1960) have shown that leachate from halogeton may alter the chemical and physical properties of 3 soils supporting salt-desert-shrub vegetation. Sodium from halogeton mulch leached into the soil was found to be most influential in causing decreased permeability and capillary rise of water, and increased crusting strength of the soils.

Since sodium from halogeton can alter the chemical and physical properties of soil, information is needed concerning the effect of altered soils on the emergence of various species of grasses and forbs. The data obtained may be useful as a basis for recommending species for revegetating halogeton infested areas and for determining what successional stages may be expected on soils altered by halogeton.

The objective of the study described was to evaluate the emergence of grasses and forbs in soil altered by leachate from halogeton. No attempt was made to evaluate the effects of limited soil moisture, soil crusting, and competition on the germination, emergence, and establishment of species. All of these factors would need to be considered, together with chemical properties of soil, to explain success or failure of seeding made under field conditions.

Procedure

The surface 5 inches of 3 salt-desert soils was sampled. The soils were supporting relatively pure stands of whitesage *(Eurotia lanata)*, shadscale *(Atriplex confertifolia)*, and saltsage *(Atriplex nuttallii)* when collected in the field. For brevity in the text and tables, soil supporting these vegetation types will be referred to as whitesage, shadscale, and saltsage soils, respectively. Finely ground halogeton mulch was placed on the surface of the soils contained in 6-inch clay pots. The depths of halogeton mulch added were none (0), 1, and 3 inches, equivalent to none (0), 27,000, and 95,000 pounds of air-dry mulch per acre.[3] Water was poured through the halogeton-soil system. The effluent was collected in aluminum dishes and poured back into the pots so that the soil would become thoroughly impregnated with any water-soluble inhibitor present in halogeton. The treatment combinations (soil and mulch depths) were compared in a randomized-block factorial design with 3 replications.

After leaching, the mulch was

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[3] *Air-dry yields of halogeton in 1959 ranged from 800 to 10,000 pounds per acre depending upon the site.*

removed, the soil in each pot was dried, ground and thoroughly mixed, and 1.75 pounds placed in 8-inch aluminum dishes for emergence trials. Chemical analyses of the 3 soils after treatment are presented in Table 1.

Table 1. Chemical characteristics of 3 soils as affected by depth of halogeton mulch.

Soil characteristic	Whitesage soil 0	Whitesage soil 1	Whitesage soil 3	Saltsage soil 0	Saltsage soil 1	Saltsage soil 3	Shadscale soil 0	Shadscale soil 1	Shadscale soil 3
	(Depth of mulch in inches)								
pH	8.1	8.2	9.2	8.2	8.3	8.8	8.2	8.2	9.2
Conductivity (E.C.x10^3)	0.76	2.90	18.50	0.76	2.75	17.00	0.80	2.50	13.00
Exchangeable cations (Me/100g):									
Sodium	0.39	4.66	10.71	0.42	5.43	13.57	0.53	3.13	10.17
Potassium	3.10	4.04	5.10	5.13	5.69	7.23	3.71	4.20	5.19
Soluble cations (Me/100g):									
Sodium	0.06	0.94	3.06	0.08	0.79	4.28	0.06	0.59	2.84
Potassium	0.04	0.05	0.14	0.05	0.07	0.17	0.04	0.05	0.11
Calcium	0.10	0.21	0.09	0.08	0.15	0.08	0.07	0.11	0.10
Magnesium	0.04	0.04	0.12	0.03	0.06	0.11	0.03	0.03	0.10

Species selected for planting in the treated soils included some which were known to be drought-tolerant and salt-tolerant, or which might invade denuded areas in the salt-desert type. Other species were included to determine their response to the treated soils. The 12 grasses and 4 forbs included in the study were: tall wheatgrass *(Agropyron elongatum)*, crested wheatgrass *(A. desertorum)*, intermediate wheatgrass *(A. intermedium)*, pubescent wheatgrass *(A. trichophorum)*, Russian wildrye *(Elymus junceus)*, medusa-head wildrye *(E. caput-medusae)*, rye *(Secale cereale)*, Pampean brome *(Bromus brevis)*, cheatgrass *(B. tectorum)*, Indian ricegrass *(Oryzopsis hymenoides)*, bulbous bluegrass *(Poa bulbosa)*, barley *(Hordeum vulgare)*, bassia *(Bassia hyssopifolia)*, halogeton, yellow sweetclover *(Melilotus officinalis)*, and Russian thistle *(Salsola kali)*.

One hundred seeds of each species were planted in an aluminum dish. After 2 weeks, the number and the average height of the seedlings in each dish were recorded. During this time the soil was kept moist to minimize the effects of limited soil moisture and soil crusting. The number emerged was coded based on 100 percent emergence in the control (no mulch). All data were analyzed statistically. Duncan's multiple range test (Duncan, 1955) was used to compare treatment main effects and interactions.

Results and Discussion

Emergence of grasses

Increased sodium and perhaps potassium in the soil (Table 1) were considered the primary cause of the effects measured. In soils altered by halogeton leachate, percent emergence of tall wheatgrass, Russian wildrye, and crested wheatgrass decreased least while emergence of pubescent wheatgrass and bulbous bluegrass decreased most. Intermediate wheatgrass, Indian ricegrass, and Pampean brome were intermediate in response (Table 2). Under ordinary circumstances tall wheatgrass would not be seeded in the salt-desert type due to lack of sufficient available moisture. Russian wildrye and crested wheatgrass, however, would be suitable for seeding halogeton-infested areas. None of the species included in the study could be recommended for seeding in soils that have

Table 2. Percent emergence of perennial and annual grasses and forbs as influenced by soil and various levels of halogeton mulch. The control (no mulch) was taken as 100 percent.

Species	Whitesage soil 1	Whitesage soil 3	Saltsage soil 1	Saltsage soil 3	Shadscale soil 1	Shadscale soil 3
	(Depth of mulch in inches)					
	(Percent)					
Perennial grasses						
Tall wheatgrass	95	58	98	54	92	54
Russian wildrye	89	13	100	26	87	28
Crested wheatgrass	85	12	90	9	106	23
Intermediate wheatgrass	72	4	80	11	95	3
Indian ricegrass	38	4	63	4	136	4
Pampean brome	63	3	79	5	87	3
Pubescent wheatgrass	52	5	68	4	47	10
Bulbous bluegrass	44	2	46	2	16	3
Annual grasses						
Barley	85	23	94	22	95	16
Rye	70	11	84	19	83	11
Medusa-head wildrye	79	3	65	12	55	3
Cheatgrass	52	2	73	5	84	2
Forbs						
Bassia	88	49	206	64	170	60
Halogeton	39	24	236	182	58	22
Yellow sweetclover	51	6	84	6	82	8
Russian thistle	54	25	193	80	70	53

been seriously altered by halogeton leachate (treated with 3 inches of mulch).

Cheatgrass or medusa-head wildrye may invade disturbed areas in the salt-desert type. One or the other may eventually occur in a successional stage with or following halogeton. Partially altered soils (treated with 1 inch of mulch) appear to be favorable for either species since the emergence of these 2 weedy annual grasses in the halogeton-treated soils was similar. Barley or rye may be used as replacement vegetation on halogeton-infested ranges since emergence of these cereal grasses was relatively high on partially altered soils. In fact, poisoned barley used for rodent control grew well in some halogeton areas. Under the heavy mulch treatment, emergence of all annual grasses was poor.

On soils treated with 1 inch of mulch, average emergence of perennial grasses was reduced 24 percent; with 3 inches, by 86 percent. The decrease was approximately the same for annual grasses (Table 2). All perennial species except pubescent wheatgrass and bulbous bluegrass maintained a relatively high percentage emergence on soils treated with 1 inch of halogeton mulch. However, on soils treated with 3 inches of mulch emergence of all species except tall wheatgrass was greatly reduced. Differences in the response of perennial grasses due to soils were not significant; however, some interesting trends were evident. Indian ricegrass and crested wheatgrass emerged better on the shadscale soil with 1 inch of mulch than on any other treated soil or the control. Emergence of Russian wildrye on the saltsage soil treated with 1 inch of mulch was the same as the control but decreased on the other 2 soils at the same mulch level. Emergence of annual species was similar on all 3 soils at each mulch level.

In addition to reducing total emergence, mulch treatment also increased the time required for emergence. In general, in relation to the time required for emergence in the control, emergence was 2 days later in the 1-inch treatment, 5 days later in the 3-inch treatment.

Emergence of forbs

Average percentage emergence for sweetclover, Russian thistle, bassia, and halogeton was 60, 86, 104, and 96 percent, respectively (Table 2). The reduction in sweetclover emergence was significantly greater than the other 3 forbs at the .05 level of probability. Average emergence of all forbs on whitesage, saltsage, and shadscale soils was 61, 120, and 77 percent, respectively.

In the whitesage and shadscale soils, emergence of forbs decreased with each increment of halogeton mulch; however, the decrease was not proportional for the 2 soils (Figure 1). On the shadscale soil, the decrease was 5 percent in the 1-inch mulch treatment, but on the whitesage soil the decrease was 42 percent in the same mulch treatment. Bassia was particularly outstanding on the shadscale soil with 170 percent emergence compared to the control. Emergence of all forbs on the saltsage soil increased to 180 percent with 1 inch of mulch compared to the control at 100 percent. Emergence of bassia, halogeton, and Russian thistle increased to 206, 236, and 193 percent of the control, respectively, on the saltsage soil treated with 1 inch of mulch. Average emergence of forbs was still about 83 percent with 3 inches of mulch on saltsage soil. Halogeton maintained a 182 percent emergence under the heaviest mulch treatment on the saltsage soil. Results indicate that of the 3 soils used in this study, the saltsage soil was the most favorable for germination and emergence of halogeton.

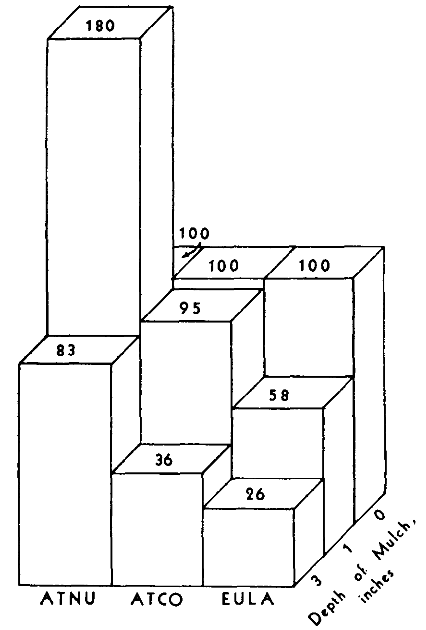

FIGURE 1. Percent emergence of forbs on soils supporting Nuttall's saltbush (ATNU), shadscale (ATCO), and whitesage (EULA) as influenced by 3 levels of halogeton mulch.

Height of grass seedlings

Grass species which emerged best in the treated soils were also those which attained greatest height in the 2-week growing period. Because of increased salt content of the treated soil, seedling height measured after 2 weeks is a reflection of retarded germination, emergence, and growth. The average height of perennial grasses was 4.2, 3.0, and 0.9 centimeters when depth of mulch was 0, 1, and 3 inches, respectively. For the annual grasses, heights were 6.2, 5.4, and 1.1 centimeters for the same mulch depths. Each added increment of mulch significantly reduced the height growth. This decrease was not as great on the saltsage soil as on the other 2 soils. Height growth of pubescent wheatgrass and bulbous bluegrass was most severely affected by the 1-inch mulch treatment. With 3 inches of mulch, the height growth of tall wheatgrass was least affected. For the annual grasses, 1 inch of mulch reduced height growth an average of 15 percent in all species. With 3 inches of mulch, cheatgrass was most severely retarded. Seedling heights averaged 2.5, 3.0, and 2.6 centimeters on the whitesage, saltsage, and shadscale soils, respectively.

Height of forb seedlings

Average heights after 2 weeks for sweetclover, Russian thistle, bassia, and halogeton were 0.9, 2.4, 1.1, and 1.0 centimeters, respectively. Average heights for the different levels of halogeton mulch were 1.8, 1.6, and 0.6 centimeters with 0, 1, and 3 inches of mulch, respectively.

The height of bassia increased with 1 inch of mulch. Height of bassia and halogeton decreased only slightly at the heaviest rate compared to no mulch, while the growth of sweetclover and Russian thistle was reduced substantially by the 3-inch mulch treatment. Height of sweetclover, bassia, and halogeton did not differ significantly on any of the soils. Russian thistle grew significantly better on the shadscale and whitesage soils than on the saltsage soil. Although percentage emergence of forbs was greatest on the saltsage soil, height growth of seedlings was not as great as on the other soils.

Summary and Conclusions

Soils which supported whitesage, shadscale, and saltsage vegetation types were treated with halogeton mulch under greenhouse conditions. Eight perennial grasses, 4 annual grasses, and 4 forbs were planted in the treated soil and the emergence and height of the seedlings were recorded after 2 weeks.

Sodium and perhaps potassium appear to be the water soluble materials responsible for reducing the emergence and growth of the species tested. One inch of mulch (27,000 pounds per acre air-dry weight) and three inches of mulch (95,000 pounds per acre air-dry weight) reduced the percent emergence and height growth of most perennial and annual grasses. One inch of mulch on the saltsage soil increased the percent emergence of all forbs except sweetclover and reduced slightly the height growth of all forbs. Under the 3-inch treatment percent emergence of tall wheatgrass, bassia, and Russian thistle was reduced about 45 percent while the emergence of halogeton was reduced an average of only 24 percent. On the saltsage soil treated with 3 inches of mulch the emergence of halogeton was 182 percent.

Results of the study indicate that soils altered by halogeton leachate are more favorable for halogeton and other low value or worthless forb species than for desirable grass species. Of the 3 soils used, the saltsage soil appears to be most favorable for germination and emergence of halogeton.

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Responses of Four Grasses at Different Stages Of Growth to Various Temperature Regimes[1]

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Grass seedling establishment has been a perennial problem on arid and semi-arid lands. Certain combinations of some of the factors that affect it result in success one year and failure the next. Temperature, which appears to be one of the primary factors influencing seedling establishment, was selected for this study.

Environmental factors such as temperature, in their extremes, restrict or kill living organisms. Within the limits of biological activity, however, the effects of gradations in temperature on the different plant processes are not well known. As with most plant-regulating factors, temperature effects are modified by and sometimes masked by other factors of the environment. The effects of specific factors vary with different species and even considerably within species (Haskell and Singleton, 1949).

Ludwig and Harper (1958), studying maize, concluded that soil temperature at planting time was an important factor in the time lapse from planting to emergence and the percentage of grains which became established as seedling. Working with fescue seed, Kern and Toole (1939), found a general decline in maximum germination with an increase in temperature from 10° to 30°C. Germination tests of seeds immediately after harvest showed a maximum germination at 10°C. As seed became progressively older, it appeared to germinate better at higher temperatures. Well-aged seed germinated best at constant temperatures as high as 20° to 25°C.

Crocker and Barton (1953) concluded that temperature affects the rate of water absorption and that both physical and chemical changes are involved. They stated that among the conditions necessary for seed germination, which have no relation to a need for pre-treatment, temperature is one of the most important. They also noted that the use of daily alternations of temperature brought about germination of many flower, grass, and vegetable seeds, which give poor seedling production under other conditions. The day and night temperatures most frequently used were 15° and 30° or 20° and 30°C.

Fayemi (1957) indicated that the rate of swelling of legume seeds was greatly influenced by temperature. The time from exposure to the initial absorption of water by the seeds became shorter as the temperature increased. At the end of 24 hours, except for seeds of crimson clover, from 90 to 100 per cent of the seeds at 25°C had absorbed water whereas only 5 to 50 per cent at the lower temperature (6.7°C.) had become swollen. The seeds kept at the low temperature did not germinate during this period but germinated readily when the temperature was raised. Water retention of swollen seeds at the low temperature did not reduce viability of any of the species except crimson clover.

Laude (1956) studied the relation of seedling emergence of perennial grasses and high soil temperature. When germinating grasses were subjected to various heat treatments, he found the nearer the heat exposure approached the time of expected emergence the fewer seedlings obtained.

The effect of temperature on water absorption, germination, and growth appears to be complex and is not altogether understood at present. As shown by Shull (1920), it is not the temperature alone which determines the rate of water uptake, germination and growth, but a complex of physiological processes. Effects of temperature treatments may often be masked by pathogens which attack plants. Once water has been absorbed, temperature becomes a most important factor in germination and growth of the plant. The effect of temperature on plants varies greatly among species, and in some cases, within species.

Methods and Materials

In September 1959, an experiment was initiated to determine the responses of four grass species to various temperature regimes at different stages of growth. Grass species used were all adapted for range or pasture seedings in the Pacific Northwest. The four species used in the study were beardless bluebunch wheatgrass (*Agropyron inerme* (Scribn. and Smith) Rydb.), hard fescue (*Festuca ovina* L. Var. *duriuscula* (L). Koch), big bluegrass (*Poa ampla* Merr.), and orchardgrass (*Dactylis glomerata* L.). The study was conducted in a controlled-environment growth chamber and in the greenhouse. A 13-hour day and an 11-hour night were maintained during the entire study. Greenhouse

[1] *Cooperative investigations of the Crops Research Division, Agricultural Research Service, U. S. Dept. of Agriculture and Washington Agricultural Experiment Stations. Scientific Paper No. 2014, Washington Experiment Stations.*

temperature was maintained at 70°F. Grasses were systematically rotated on the greenhouse benches every other day.

Five temperature regimes at 15 Fahrenheit degree intervals were selected for the growth-chamber phase of the study. These temperatures were (1) day 55°, night 40°; (2) day 70°, night 55°; (3) day 85°, night 70°; (4) day 100°, night 85°; and (5) day 115°, night 100°. All temperatures in this paper refer to degrees Fahrenheit. This study was set up as a randomized block design with five replications. Each pot was considered a plot. Grasses were grown in sterilized Palouse silt-loam soil in six-inch clay pots. Ten seeds of a species were planted per pot. Grasses were planted at six-day intervals for a total of five planting dates of 20 pots each. At the fifth and final planting date there were five replications of each species which were of the following ages: just planted, 6, 12, 18, and 24 days old. During the course of the study this entire procedure was repeated five times, once for each temperature regime.

Germination counts were made on all grasses and the maximum height of each seedling was recorded before placing pots in the growth chamber. At the same time, grasses which had been planted 18 and 24 days were thinned to three seedlings per pot to reduce root competition. The entire series was then moved from the greenhouse to the growth chamber and subjected to one of the five temperature regimes for 18 days. Upon removal from the growth chamber, germination counts were again made and plant heights were recorded for all species in all replications. In an attempt to ascertain immediate effects of each temperature regime, two of the five replications were randomly selected for intensive immediate study. Grasses from these replications were clipped at soil level, oven-dried, and weighed. The roots were carefully washed out and measured, and lengths were recorded.

The three remaining replications were returned to the greenhouse for six weeks to determine the carry-over effects of the growth chamber temperature regimes and recovery potential of the various grasses. However, because of a logistical error grasses subjected to the 55° temperature regime had a 10-week recovery period. Seedlings not thinned prior to introduction into the growth chamber were thinned to three per pot when about 30 mm. high. At the conclusion of the recovery period in the greenhouse, tops were harvested, oven-dried and weighed. Roots were also washed out, oven-dried and weighed.

During all phases of the experiment, plants were watered frequently and uniformly in an attempt to prevent soil moisture from becoming limiting.

Results And Discussion

Germination in Growth Chamber

A separate analysis of variance (Table 1) was run on each measured plant characteristic. Analysis of variance for germination (Table 1) indicated that effects of differences in temperature and differences among species were both significant at the 0.01 level. Effects on stage of growth, while shown to be significantly different, actually have little meaning because the seeds were planted at different times. The mean values (Table 2) for the five temperatures (average of the four species and their five planting dates) indicate that extreme temperature regimes of 55° and 115° were unsatisfactory for germination with values of 11.0 and 14.3 per cent, respectively. Mean values of 43.0 per cent for the 100° temperature regime and 47.6 per cent for the 70° regime were significantly higher than the means for the other temperature regimes but were not significantly different from each other (Table 2).

Seeds planted and immediately subjected to temperature treatment, germinated well at the three middle temperature regimes. All species when planted and immediately sub-

Table 1. Analysis of variance for six characteristics of four grasses subjected to various temperature regimes.

Source of Variation	Measurements While in Growth Chamber								Recovery Measurements			
	Germination		Top Elongation		Top Weight		Root Elongation		Final Top Weight		Final Root Weight	
	D.F.	Mean Square	D.F.	Mean Square	D.F.	Mean Square	D.F.	Mean Square	D.F.	Mean Square	D.F.	Mean Square
Temperature (T)	4	454.9**	4	113872**	4	0.0609**	4	39347**	3	0.0318**	3	0.1555**
Stage of Growth (S)	2	163.0**	4	5236**	4	0.1551**	4	72772**	4	0.0761**	4	0.3257**
T x S	8	42.1**	16	2804**	16	0.0095**	16	2743**	12	0.0044	12	0.0093
Grass Species (G)	3	58.3**	3	53525**	3	0.8883**	3	18696**	3	0.1213**	3	0.4496**
T x G	12	11.9	12	5403**	12	0.0058**	12	737	9	0.0094**	9	0.0192**
S x G	6	21.1**	12	5740**	12	0.0168**	12	842	12	0.0071**	12	0.0191**
T x S x G	24	8.0	48	699	48	0.0018	48	863	36	0.0023	36	0.0043

**Indicates significance at the 0.01 level jected to temperature treatments failed to germinate while in the growth chamber at the 55°F. regime. However some limited germination did occur after the pots were returned to the greenhouse. Differences between species for all temperatures and stages of growth were highly significant (Table 1). Highest over-all germination percentage (39.8) was exhibited by hard fescue. Beardless bluebunch wheatgrass, big bluegrass, and orchardgrass followed with 33.1, 24.5, and 20.1 per cent, respectively. Seeds of hard fescue germinated best at 100° with an average of 92 per cent. Beardless wheatgrass and big bluegrass both exhibited maximum germination at 85° with 70 and 68 per cent, respectively. Seeds of hard fescue germinated best at 100° with an average of 92 per cent. Beardless wheatgrass and big bluegrass both exhibited maximum germination at 85° with 70 and 68 per cent, respectively. An increase of 15 degrees caused a considerably greater decrease in germination than did a decrease of 15 degrees for these grasses. Orchardgrass exhibited fair germination for the three middle temperature regimes. A maximum of 56 per cent germination was obtained at 70° with complete inhibition of germination at 55° and 115°.

Extreme temperatures had a less pronounced effect on seeds which had been planted six days before introduction into the growth chamber. Differences were especially evident for beardless bluebunch wheatgrass and hard fescue at the 55° temperature regime and beardless wheatgrass, big bluegrass and orchardgrass at the 115° regime. Seed of the grasses under study were more affected by extreme temperatures during the first six days after planting. Seeds which had been planted 12 days before introduction into the growth chamber had, in most cases, completed germination. Orchardgrass, however, did increase in germination at 70°, even after the 12 days in the greenhouse. The 15° day and night temperature variation apparently results in germination of some seeds which would not have germinated at the nearly constant temperature of the greenhouse. Extreme temperatures while in the growth chamber appeared temporarily to inhibit germination of all species. Seeds of all species, however, continued to germinate upon being returned to the greenhouse.

Top Elongation

Analysis of variance for top elongation indicates that all species were greatly affected by the various temperature regimes (Table 1). Stage of growth, species, and their interactions all varied enough to be highly significant. Mean values for top elongation and least significant ranges over all stages of growth and all species are shown in Table 2. A marked increase in top elongation was indicated as temperature was increased from the 55° to the 85° temperature regime with 8.5 mm., 62.7 mm., and 79.4 mm. for the 55°, 70°, and 85° temperatures, respectively. The 100° temperature exhibited a slight but insignificant decrease from the 85° temperature. A further increase in temperature to 115° resulted in a highly significant decrease in top elongation (Table 2).

Seeds planted at the beginning of the temperature treatment germinated and initiated growth during the 18-day period in the growth chamber, appeared to benefit most from the 100° temperature, and did well at the 70° and 85° temperature, but were greatly inhibited at 55° and 115°. Grasses which had been planted six days before temperature treatment made maximum top elongation at the 70° temperature regime. Top elongation de-

Table 2. Mean effects of temperature on growth responses of four grass species and their least significant ranges.[1]

Characteristics					
GERMINATION (100)[2]					
Temperature F°	55	115	85	100	70
Mean (Percent)	11.0	14.3	31.0	43.0	47.6
TOP ELONGATION (100)					
Temperature F°	55	115	70	100	85
Mean (mm.)	8.5	14.7	62.7	74.2	79.4
TOP WEIGHT (40)					
Temperature F°	55	115	70	100	85
Mean (mg.)	1.84	3.66	9.38	9.39	10.44
ROOT ELONGATION (40)					
Temperature F°	55	115	70	85	100
Mean (cm.)	5.9	10.6	12.3	12.6	13.9
FINAL ROOT WEIGHT (60)					
Temperature F°	100	115	70	85	55
Mean (mg.)	4.72	4.99	6.23	9.16	9.60[3]
FINAL TOP WEIGHT (60)					
Temperature F°	115	100	70	55	85
Mean (mg.)	8.7	10.1	14.7	18.3[3]	20.6

[1] Any two means not underscored by a broken line or a solid line are significantly different at the 0.05 level. Any two means not underscored by a solid line are significantly different at the 0.01 level.

[2] Numbers in parentheses indicate number of observations.

[3] These means not directly comparable as plants at the 55° temperature regime were allowed a 10 rather than 6 weeks recovery period.

creased slightly as the temperature was increased to 100° and decreased rapidly with further increase in temperature. Grasses planted 12 and 24 days before temperature treatment made greatest top elongation at the 85° temperature regime.

Beardless wheatgrass, hard fescue, and orchardgrass exhibited maximum top elongation at the 85° regime. Big bluegrass exhibited maximum elongation at 70° but growth decreased as the temperature increased to 100°. The highest and lowest temperatures greatly inhibited elongation of all species.

These data indicate rapid top elongation between 70° and 100°. Also, there appeared to be a stimulation of top growth from the relatively high temperature of 100° when the grass was emerging. These data indicate the crucial range for top elongation to be between 55° and 70°. Between these two temperatures there was an average seven-fold increase in top elongation. All species studied exhibited further growth increases from the 70° to the 85° regimes at the oldest stage of growth.

Top Weight While in Growth Chamber

Analysis of variance for top weight while in the growth chamber indicates that temperature, stage of growth, species, and their interactions are all highly significant (Table 1). The 85° temperature regime resulted in the greatest average top production over all stages of growth (Table 2). When the temperature was increased or decreased by 15° increments from the 85° temperature regime, top weight was reduced significantly. Mean top production values of 10.44, 9.39, 9.38, 3.66, and 1.84 mg. were found for 85°, 100°, 70°, 115°, and 55° respectively. Top production was significantly reduced between 55° and 70° and between 100° and 115°.

Grasses planted 0 and 18 days before introduction into the growth chamber made their greatest growth at 100°. Grasses just emerging at the time of introduction into the growth chamber made maximum growth at 70°. Grasses planted 12 and 24 days before temperature treatment made their maximum growth at 85°. Top production appears to be significantly influenced by temperature, the magnitude of the effect depending on how far the temperature diverges from the optimum. Of the temperatures studied, 70° resulted in greatest top production for big bluegrass and 85° for the remaining species.

Root Elongation While in Growth Chamber

Analysis of variance for root elongation indicates a highly significant variation between temperature, stage of growth, and species (Table 1). The most pronounced increase in root elongation due to temperature was a two-fold increase of 5.0 cm. to 12.3 cm. from the 55° to the 70° regime. Mean root elongation of 12.6 cm. for the 85° regime was not significantly different from the root elongation of the 70° regime (Table 2); however, the mean values for both 85° and 70° were significantly less than the 13.9 cm. mean growth at 100° which appeared to be optimum for root elongation. The 115° regime resulted in a highly significant decrease in elongation as compared with the 100°, with a mean value of 10.6 cm.

Grasses planted 0, 6, and 18 days before being placed in the growth chamber exhibited maximum elongation at 100°. Grasses planted 12 days prior to being placed in the growth chamber made maximum root growth at the 85° regime. Of the grasses planted 24 days before being placed in the growth chamber, beardless wheatgrass and orchardgrass showed a pronounced stimulation at the 115° regime. Hard fescue and big bluegrass, however, exhibited maximum elongation at the 85° regime.

Final Top Weight

Mean values showing residual effect of temperature on top weights indicate a definite residual effect of the various temperature regimes (Table 2). The effect of the inhibition of normal growth as a result of the 115° treatment was especially pronounced, even after the six-week time lapse since treatment. Grasses at 55° would be expected to have the most top growth, since their recovery period was four weeks longer than that of grasses receiving other treatments. This was true in less than 50 per cent of the observations. These data suggest that 18 days at 55° put the grasses tested about four weeks behind in top production as compared with those at the 85° regime. Temperature, stage of growth, grass species, the interaction of temperature and growth, and the interaction of stage of growth and species were all highly significant (Table 1). Means for final top weight indicate that even after a six-week recovery period, production at the 85° regime was significantly higher than any of the others (Table 2). Presumably, if recovery periods were equal, the mean values for the 55° regime would have been significantly below the mean values of 14.7 mg. and 20.6 mg. for the 70° and 85° regimes, respectively. The values of 10.1 mg. for the 100° regime and 8.7 for the 115° regime were not significantly different from each other but were significantly lower than the value for the 70° regime (Table 2).

These data suggest that the two high temperature regimes, 100° and 115°, had a prolonged deleterious effect on the grass seedlings. Following the six-weeks recovery period in the greenhouse, top weights of plants subjected to the two high temperatures were still significantly lower than top weights of plants subjected to the 70° and 85° temperatures. As stated before, final top weights of seedlings subjected to the 55° temperatures cannot be directly compared as they were allowed a ten-week recovery period.

Final Root Weight

Final root weights follow a similar pattern as final top weights. Analysis of variance for final root weight shows temperature, stage of growth, species, and the interactions of these variables to be significant at the 0.01 level (Table 1). Final root weight was greatest at the 85° regime and this value was highly significantly different from all other values for root weight. This apparently was a reversal of the trend immediately following temperature treatment where root growth exhibited an optimum growth at 100°. Six weeks after treatment, root growth for the 85° regime was 9.16 mg., about double that for the 100° regime (4.72) (Table 2). Mean values for the 100°, 115°, and the 70° regimes were not significantly different. The final root weight for the 55° regime should not be compared because of the difference in recovery period.

Six weeks after temperature treatment, there appeared to be complete masking of the immediate root stimulation at the higher temperature regimes; plants subjected to the 85° regime produced maximum root production. In some instances, as with beardless wheatgrass at the oldest stage of growth, the effects of the temperature stimulation in the growth chamber were still evident six weeks after removal.

Summary And Conclusions

Results of germination analysis on beardless bluebunch wheatgrass, hard fescue, big bluegrass, and orchardgrass indicated that germination is inhibited or greatly reduced at temperatures above 100° or below 70°. Germination was fair between 70° and 100°. Orchardgrass germinated best at the lower temperature and beardless wheatgrass, hard fescue, and big bluegrass at the higher temperatures. No apparent detrimental carry-over effects from extreme temperatures were observed after returning seeds to greenhouse conditions.

A pronounced increase in top production was exhibited as the temperature was increased from 55° to 85°. The 85° regime resulted in the greatest top growth over all stages of growth. Little growth occurred at 55°. A sharp decline in top production took place at 115°.

In contrast to the decline in top growth from 85° to 100°, root growth as measured by elongation was greatest at 100°. The stimulation of root elongation at 100° was followed by an over-all decrease in both top and root production during the six-week recovery period.

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Variable Plot, Square Foot Plot, and Visual Estimate for Shrub Crown Cover Measurements[1]

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Range management procedures often require an estimation of shrub cover for complete evaluation of vegetation characteristics. Survey studies conducted over large areas necessitate rapid estimation. However, procedures associated with reduced time requirements are often inexact and variable. Since the inherent characteristics of a survey study often require evaluation by several workers with varying degrees of ability and experience, an acceptable cover estimation method must be accurate, rapid, and consistent among individuals.

The study reported here was conducted in the Big Horn Basin of western Wyoming by University of Wyoming personnel.[2] Three men evaluated three types of shrub cover with three methods of estimation—visual estimate, square-foot plot, and variable plot. The object of this evaluation was to compare the three methods and to appraise the re-

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[2] *Acknowledgement is extended to graduate students Clayton Williams and Otto Schipporeit for their assistance and interest in this investigation.*

lationship of data acquired by different personnel.

Review of Literature

Estimates of vegetation cover for range inventry studies were originated in 1907 by Jardine. His method, known as the reconnaissance method, was used on a team basis and consisted of estimating percentage of ground cover and the percentage composition of the species in the vegetation (Pickford, 1940). Although widely adopted, the method has been criticized, since accuracy of results depended largely upon the judgment and observational powers of the individuals using it (Smith, 1944).

A number of plot sizes have been developed for cover estimation procedures (Brown, 1954). Armstrong (1907) used a frame one square foot in area and subdivided into 144 square inches by cord stretched across the frame. He counted squares of bare surface and squares occupied by vegetation. With practice and care, he was able to obtain accurate estimates of cover by examining 6 to 10 frames on a representative portion of turf. However, the method is not altogether satisfactory since estimation of tall plants is difficult and location by "random" throws tends to be biased (Greig-Smith, 1957).

The variable plot method was first proposed by Bitterlich (1948) in Austria. By this system, timber-volume estimates were obtained without establishing plot boundary lines. Basically, the procedure consisted of viewing all trees visible from a given point and counting all those whose diameters appeared greater than a hand-held angle gauge. The total count divided by the number of sampling points, multiplied by a constant derived for a given angle, gave an estimate of average basal area per acre. Grosenbaugh (1952) introduced the method to American foresters. Subsequent modifications have been developed to permit use of the method on shrub and grass types.

Cooper (1957) conducted variable plot studies on shrub types of southern Arizona. Modifications were developed for the direct conversion of shrub counts to percent cover data through division-factor constants for various sighting angles as projected by different crossarm lengths. A comprehensive derivation of variable plot principles and factor equations was presented. Variable plot studies were compared with direct shrub cover measurements and line interception data in three vegetation types. The variable plot estimates closely approximated the other methods in shrub stands of less than 35 percent cover and were much less time consuming.

Kinsinger, *et al.* (1960) compared different vegetation types of northern Nevada to evaluate variations of line interception, variable plot, and loop methods of shrub cover estimation as developed by different observers. Differences between observers and between plots of a vegetation type were negligible by variable plot analysis. Individual shrubs were difficult to distinguish when cover was more than 20 percent.

Hyder and Sneva (1960) constructed an apparatus of angle iron for application of variable plot studies on bunchgrass range of Oregon. Basal cover estimates were significantly greater by variable plot than by line intercept; however, the differences were not consistent among species. Differences between observers were slight. Reduction of reading time appeared to be the greatest advantage of the variable plot method.

Procedure

Crown cover studies were conducted on three shrub types—Nuttal saltsage (*Atriplex nuttallii* S. Wats.), big sagebrush (*Artemisia tridentata* Nutt.), and greasewood (*Sarcobatus vermiculatus* (Hooki) Torr.). The sites were relatively uniform over an area approximately 200 feet in diameter and typical of much of the rangeland of western Wyoming. Saltsage (Figure 1) is a half-shrub, rarely over a foot in height with well defined plant units. The sagebrush (Figure 2) in this area is about 2.5 feet tall, while the greasewood (Figure 3) ranges from three to five feet in height. Individual bushes of the latter two species are, in many cases, not well defined.

Three observers collected individual data by three methods. Visual estimates were determined on a reconnaissance basis while standing in the study site and recorded in units of 5-percent crown cover. Cover data were obtained from transects of 10 frames, each a square foot in area. Each observer located plots independently of the others but within the general study area. Variable plot estimates were conducted from a single location point within each of the study sites.

A wooden angle gauge (Figure 4) was constructed similar to that described by Cooper (1957). The overall length, or the distance from eyepiece to crossarm, was 30 inches. Peephole diameter of the eyepiece was 5/32 of an inch. Four lengths of crossbar with division constants of 1, 2, 4, and 6 were used and individual readings obtained by each of the angles. The crossbars were easily exchanged but were held firmly in the cross lap cuts.

Before the reported study, survey procedures with the three methods were conducted throughout the region for two weeks. All observers were thus able to estimate shrub cover with reasonable uniformity. Emphasis was placed upon the concepts of recognizing the influence of plant growth form and height upon visual and square foot plot estimations. Variable

FIGURE 1. The saltsage site is characterized by the sparse stand of well-defined and easily identifiable plant units.

plot determinations involved the study of delineating plant units of various species.

Results and Discussion

Mean values of percent crown cover by shrub type as evaluated between methods and between observers are presented in Table 1. Differences between cover values of shrub types are not related and are of little importance as a measure of variation in this study. Determination of cover by visual estimate were equal by the three observers on the saltsage site but were extremely variable on the other two sites. This would appear to be a function of the growth form and height of the different species. Visual estimation must, of necessity, be considered a gross procedure with an expected high degree of variability between observes unless intensive training and checking procedures are conducted. Cover estimates from transects of square foot frames appear to be of little value for shrub cover determinations. Observer differences were great and the overall averages of cover by this method were much less than those by the other methods. It seems obvious that this method cannot be successfully applied to shrub cover determinations.

Mean cover values of variable plot data as presented in Table 1 indicate relatively close estimates between observers on given sites. Further evaluation of the data by standard statistical procedures (Ostle, 1956) yields interesting sources of variation. Mean squares for relation of variance to shrub types, gauge angles as determined by crossarm lengths, and observers are presented in Table 2. Shrub types introduced an expected highly significant variation in cover estimates. Other sources of significant variation in mean squares were crossarm lengths, observes, and the interaction between shrub types and gauge angles.

The highly significant variation in different crossarm lengths appeared to result from the higher average cover estimation values of the next to the longest crossarm length—that of 4-15/64 inches (Table 3). Interaction effects of the saltsage data tend to modify the deviation but appear to be of slight significance. Computation of the least significant difference (L. S. D.) shows the average crown cover value by this length to be significantly different from all others at the

FIGURE 2. The dense stand of big sagebrush is characteristic of much of the study area.

FIGURE 3. Many bottomland areas are dominated by greasewood.

5-percent probability level. The others are uniform and indicate little variation.

Effective sampling radius becomes larger with a smaller angle and thus, if a change in estimation occurs, one would expect it to be downward. This follows from the concept that, as the distance of measurable plants from the observer increases, the probability increases that hidden bushes will not be counted and that separate plant units will be combined into single counting units. Confirmation of this hypothesis is noted in the observed lower estimates of the shorter crossarms on the sagebrush and greasewood sites (Table 3).

The low estimates by the longest crossarm indicate other agents that can cause variation. The basic concept of the variable plot technique assumes a crown measurement procedure on a horizontal plane. This is virtually impossible in field application, since the observer must usually be above the bushes to be able to see and distinguish them. This difference in observer and plant height increases the measuring distance to the shrubs. For a given gauge angle, the greater the sighting distance, the greater the shrub diameter must be to be counted. Since this effect is most pronounced near the observer, proximate bushes could easily be ignored and not counted.

Therefore, subject to the interaction effects of plant height, it would appear that a crossarm of 4-15/64 inches will develop the greatest accuracy for the vegetation under study. Interestingly enough, this concept results from the fact that cover data by this length crossarm are significantly

Table 1. Means of percent cover of three shrub types as determined by three methods by three individuals.

	SHRUB TYPES								
	Nuttall Saltsage			Big Sagebrush			Greasewood		
Observer	Visual Estimate	Sq. Ft. Plot	Variable Plot[1]	Visual Estimate	Sq. Ft. Plot	Variable Plot	Visual Estimate	Sq. Ft. Plot	Variable Plot
A	15.0	7.9	12.98	30.0	5.2	22.18	15.0	3.5	14.38
B	15.0	.9	12.25	20.0	8.7	20.12	10.0	6.0	11.15
C	15.0	7.8	12.05	15.0	14.4	24.08	5.0	5.1	13.75
Average:	15.0	5.5	12.43	21.7	9.4	22.13	10.0	4.9	13.09

[1]Each figure is an average of cover estimates with four different angles as determined by four crossarm lengths.

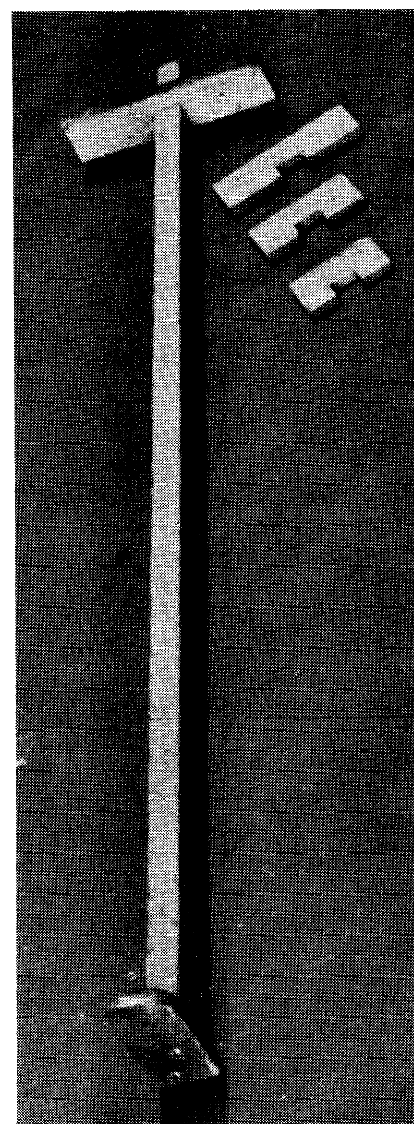

FIGURE 4. The Wooden angle gauge was prepared for rapid exchange of crossarms.

Table 2. Mean squares of crown cover estimate by variable plot procedures for relation of variance to shrub types, crossarm lengths, and observers.

Source of Variation	Degrees of Freedom	Mean Square
(S)hrub Type	2	352.28**
(C)rossarm Length	3	31.33**
(O)bserver	2	16.99*
S x C	6	8.96*
O x S	4	5.63
C x O	6	.96
Error (S xC x O)	12	2.80

*Significant at the 5-percent probability level.
**Significant at the 1-percent probability level.

different from the others. Also, the foregoing conclusions and the intuitive results of a summers' application of the variable plot technique are in accord.

The significance of the interaction between shrub types and crossarm lengths in the analysis of variance (Table 2) appears to be due to the differences in saltsage height and growth form from the other species. Crown cover estimates of sagebrush and greasewood increased from the shortest to the 4-15/64 inch crossarm length and decreased with the longest length. Saltsage estimates, however, were relatively uniform by the shorter lengths and decreased markedly with the the longest crossarm. The low estimate of saltsage by the longest crossarm length (Table 3) can be explained in light of the height differential between observers and plants. Further, the uniformity of estimate with the other three lengths follows with the low plant stature, wherein fewer countable plants would be missed than would be the case with the taller species.

The significant observer variation in the analysis of variance of Table 2 results from a very interesting sample bias situation. It will be noted in Table 1 that the average variable plot cover estimate of saltsage by observer "B" is intermediate between those of the other two observers. In the sagebrush and greasewood types, his estimate is noticeably lower than the other. The tendency of observer "B" to underestimate is also noted in Table 3. Least significant difference (L. S. D.) at the 5-percent probability level is less than the differences between observer "B" and the others.

The foregoing would be difficult to explain except that observer "B" was only four feet nine inches tall and observers "A" and "C" were six feet tall. On the saltsage site, the 15-inch differential in observer height evidently did not influence the overall estimate. However, on the big sagebrush and greasewood sites, lower estimation of cover by the shorter man evidently resulted from his inability to see and distinguish the individual plants as far from the observation point as the taller workers. Further inference from these data would indicate that any difference in observer height could result in variation of cover estimates, depending upon the height and growth form of the plants.

Summary and Conclusions

Range survey methods of shrub crown cover measurements must be rapid, accurate, and consistent among individuals. Studies were conducted to compare percent crown cover estimates from three methods of evaluation on three shrub types by three observers.

Cover values obtained by the visual estimation technique were variable. However, data indicated that relatively accurate determinations could be obtained with intensive training and repeated checks.

Transects of square foot plots appeared to be of little value as a shrub cover estimation technique. Observer differences were great and crown cover values were markedly lower than those obtained by the other methods.

Variable plot studies were conducted with four gauge angles as determined by different crossarm lengths. Evaluation of the data by analysis of variance indicated significant differences in shrub types, crossarm lengths, observers, and the shrub type X crossarm length interaction.

Variation due to crossarm length appeared to be due to characteristics of plant height and growth form and to differences in effective sampling radius as reflected by the different

Table 3. Means of percent cover by variable plot estimation of crossarm lengths and observers among shrub types and crossarm lengths and shrub types among observers.

	Crossarm Length (inches)				
Observer	2-29/64	3.0	4-15/64	6.0	Average[1]
A	15.03	16.17	18.83	16.00	16.51
B	12.77	14.77	17.17	13.33	14.51
C	15.57	15.43	19.83	15.67	16.62
Average[2]	14.46	15.46	18.61	15.00	
Shrub Type					
Saltsage	13.13	13.07	13.83	9.67	12.42
Sagebrush	19.07	21.77	25.67	22.00	22.13
Greasewood	11.17	11.53	16.33	13.33	13.09

[1]L. S. D. of 1.49 at 5-percent probability level.
[2]L. S. D. of 1.72 at 5-percent probability level.

gauge angles. The smaller the crossarm length, the greater the sampling radius, and when this distance becomes greater, the probability increases that the observer will underestimate the number of countable shrubs. On sagebrush and greasewood the two shorter crossarm lengths consistently underestimated cover, but on saltsage they did not. The estimates from the longest crossarm appeared to underestimate cover because of the differential in observer and plant heights. The next to the longest crossarm (4-15/64 in.) appeared to provide the best estimate of cover subject to the shrub type interaction, which tended to modify the results.

As observer height above the bushes increases, fewer countable bushes will be overlooked. Observer "B" was 15 inches shorter than the others, and consistently estimated less cover on sagebrush and greasewood. However, his estimates on saltsage were intermediate between the others.

Field studies should be conducted to determine the most accurate gauge angle subject to shrub height and density before range survey use of the variable plot technique. In addition, inherent variations in data due to different observer heights must be evaluated. With a minimum of procedural control the variable plot method of shrub crown cover estimation appears to be a highly satisfactory tool for range surveys.

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Utility of Soil Classification Units in Characterizing Native Grassland Plant Communities in the Southern Plains

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Environmental factors instrumental in the development of a native plant community and the soil on which it occurs have much in common and are interdependent in many respects. The nature of the relationship between kind of soil and kind of plant community is becoming more apparent as a result of joint field evaluations by soil scientists and range conservationists in connection with the National Cooperative Soil Survey.

Millions of acres of rangeland are now being mapped by this survey. In portions of the Plains states, sufficient adjoining counties have been mapped to provide contiguous soil maps for distances of several hundred miles. For example, detailed soils maps are available, with but few interruptions, from eastern Oklahoma to eastern New Mexico.

Within the next decade it is probable that most privately owned rangelands in the Southern Plains will be mapped by such surveys. Therefore, the contribution that these surveys make to rangeland resource inventories is of direct concern to rangeland users.

Relationship Between Soil Classification Categories and Native Grassland Plant Communities

Soil is the upper part of the earth's mantle in which land plants grow. The lower limit of soil has not been clearly defined but it includes the material in which most of the plant roots grow.

The characteristics of the soil at any given point depend on the properties of the parent material from which it was formed, and the extent to which this material has been changed by nature. An extremely young soil has been altered very little. Most soils, however, have been appreciably altered by the environmental forces of nature.

The degree that parent material may be changed in the formation of a soil depends on (1) the resistance of the material to change, (2) climate, (3) vegetation and other biological activity, and (4) time. Relief or topography modifies the macroclimate of an area, resulting in localized soil and plant microclimates. Thus the soil is both a result of the environment and a part of the environment.

In the National Cooperative Soil Survey, soils are indentified, described, and classified in accordance with a nation-wide classification system (Kellogg. 1936, Baldwin et al. 1938, Riecken and Smith, 1949, Thorp and Smith. 1949, Soil Survey Manual. 1951). The taxonomic units of the classification system, beginning at the highest level, include order, suborder, great soil group, family, series, and type.[1] Mapping units are defined in terms of kind and properties of taxonomic units. The detail of mapping varies with the nature of the land and its potential uses. Generally the delineations on soil maps of rangeland areas include soil series or types or combinations of these. In addition, soil phases such as slope, erosion, and stoniness may be mapped as subdivisions of taxonomic units when these factors are significant to the use and management of the land.

Numerous field observations indicate that the most definitive relationship between kind of soil and kind of native plant community exists at the soil series, soil type, and soil phase level of differentiation. Prior to a more detailed consideration of this relationship, a brief evaluation of the significance of higher classification categories is warranted.

1. The Soil Order:

The soil order includes zonal, intrazonal, and azonal soils.

Zonal soils are formed on well drained areas from materials that are not extreme in texture or chemical composition. They have well developed profiles. The characteristics of these soils are the best reflection of the climatic and ecological zone in which they occur. In the Southern Plains, they are best typified by deep, loamy textured, well drained soils of nearly level convex upland slopes.

Intrazonal soils also have well developed profiles, that is, the characteristics of the parent materials have been appreciably altered during soil formation. Most of these soils occupy flat or depressed positions in the landscape which are more moist than typical for the area. In some places the drainage also has been or is restricted, resulting in the accumulation of excess salts in semiarid or arid climates. Some intrazonal soils are the result of parent materials being unusually high in calcium or sodium salts. These soils reflect the influence of climate to a lesser degree than zonal soils.

Azonal soils are young soils lacking well developed profiles. They are young because the parent materials have been in place a very short time, geologic erosion is rapid, the soil climate is more arid than common for the area, the parent materials are very resistant to alteration, or because of various combinations of these factors. Alluvial soils, Lithosols, and Regosols are included in this group.

Zonal, intrazonal, and azonal soils are not limited in occurrence to a specific climate. Each group includes many kinds of soil. Even in a given locality there generally are several kinds of zonal soils with significantly different soil characteristics and different kinds of native plant communities. The same is true of intrazonal and azonal soils. In a specific locality the soils of these groups have many species in common, however, the grouping of these species into characteristic plant communities is highly variable. The native plant communities of zonal soils best reflect the potential vegetation of a climate, thereby imparting a characteristic aspect to the native plant cover of extensive landscapes.

2. The Suborder:

The suborder includes six subdivisions of zonal soils, three of intrazonal soils, and one of azonal soils. Examples of zonal soil groupings are as follows:

a. Light-colored soils of arid regions.

b. Dark-colored soils of semiarid, subhumid, and humid grasslands.

c. Light-colored podzolized soils of timbered regions.

Only very broad relationships exist between native plant communities and the soil suborder. Subdivisions into various groupings of zonal soils serve to characterize major life forms of vegetation such as desert shrub, grassland, and forest. However, in each subdivision there are significant differences in kinds of soil and kinds of native plant communities.

3. Great Soil Group:

A great soil group includes soils with similar profiles differing mainly in texture, structure, and mineral composition. There are about 21 zonal great soil groups, 13 intrazonal, and 3 azonal. As contrasted to the order and suborder, soils of a great soil group are limited in occurrence to a more specific kind of climate. Therefore, this category is useful in characterizing the life form and structure of extensive native plant communities of regional distribution. In the Southern Plains, for example, mixed tall - and mid - grass plant communities are associated with the Reddish Prairie soil group, mixed mid and short grass communities with Reddish Chestnut soils, and short grass communities with some of the Reddish Brown soils.

Care must be taken to avoid over-generalization in ascribing a specific kind of plant community to a great soil group. Even the zonal soils of a great soil group frequently have sufficient

[1] *Some revisions in the classification system have been proposed. This discussion is based on the system in current use.*

differences in soil characteristics to result in significant differences in native plant communities. For example, some zonal soils of the Reddish Brown soil group support plant communities dominated by short grasses with negligible amounts of mid grasses while others support plant communities dominated by mid grasses with minor amounts of short grasses. Therefore, a great soil group lacks the specificity required to characterize a definitive plant community for a local land area.

4. The Soil Family:

The soil family has not been used much in the past to characterize native vegetation. During the past several years, however, soil scientists have devoted considerable effort to grouping closely related soil series into families. It is anticipated that climatic and other phases of these families will have considerable utility in helping to identify native pant communities of similar potential.

5. The Soil Series, Type, and Phase:

Soils included in a series are developed from parent material that does not differ appreciably in texture or mineral composition. They have horizons similar as to differentiating characteristics and arrangement in the soil profile. The texture of the "A" horizon may differ but many series have only one texture. These are monotype series.

The soil type is a subdivision of a soil series. All features of the soil types of a series are comparable except for the texture of the "A" horizon. Thus the Dalhart series includes several soil types such as Dalhart sandy loam, Dalhart fine sandy loam, and Dalhart loam. These are comparable soils except for surface soil texture.

Phases of a soil type are differentiated on the basis of such characteristics as stoniness, alkalinity, slope, depth, and degree of accelerated erosion. Major emphasis is given to characteristics which are significant to uses of the soil. On rangelands, specific emphasis is given to those phases which influence plant growth and, therefore, the nature of native plant communities. Phases of series, families, and great soil groups may also be recognized.

The geographical distribution of a zonal soil series is limited to an area of land having substantial similarity in major environmental factors. Thus the Dalhart series and its associated types, for example, is limited to a portion of the Southern High Plains having gentle relief and a semiarid climate in which average annual precipitation is from 16 to 20 inches. Seasonal distribution of precipitation, ranges in temperature, and evaporation rates are reasonably comparable throughout the area in which the series occurs.

Correlation Between Native Plant Communities And Soil Types

Correlations with specific native plant communities can best be made with soil types and phases of types. In the absence of major disturbance a relatively distinctive plant community identified by a characteristic grouping of plant species is apparent for a specific soil type. This characteristic grouping of species is not evident in terms of a precise composition percentage of the individual species that reoccurs wherever the soil type is found. However the relative proportion of species in terms of dominance and association is evident. This plant community is not one that is restricted to presumed pristine relict areas. Its occurrence is generally apparent on a number of pastures or grazing units that have had conservative grazing use for a number of years and in which the soil has not been subjected to pronounced physical deterioration. As an example, Richfield silt loam is a zonal soil occurring on gently undulating uplands in southwestern Kansas and the Oklahoma panhandle. Throughout this area this soil type is characterized by the dominance of blue grama *(Bouteloua gracilis)* and the occurrence of buffalo grass *(Buchloe dactyloides)* as the major associated species. Each soil type occurring in the same area as Richfield silt loam has its own characteristic plant community, some of which are similar to that found on Richfield silt loam, and others that are markedly different.

Plant communities that vary materially from the characteristic grouping of species found on an individual soil type occur as a result of varying degrees of disturbance and physical soil deterioration. However, careful observation of the numerous examples normally available within the area of occurrence of the soil type generally provides a clear pattern of the characteristic plant community.

While each soil type having major differences in soil characteristics from another soil type supports a relatively distinctive kind of plant community, those soil types having closely related soil characteristics support essentially similar kinds of native plant communities. Therefore, depending on the degree of plant community differentiation desired for a specific purpose, it is feasible to group closely related soil types to express similar plant community potentials. For example, Ulysses silt loam, Richfield silt loam, and Pullman silt loam support plant communities dominated by blue grama with buffalo grass as the principal associated species. Despite minor variations in the characteristic plant communities of these soil types, they may be grouped for the purpose of developing range management and range improvement plans.

The differences in kinds of native plant communities found on the several types of a soil series may be greater than the differences found on similar soil types of closely related soil series. As an example, the plant community found on Dalhart loamy fine sand is characterized by a mixture of mid, tall, and short grasses, while the plant community of Dalhart loam is dominated by short grasses. However, the plant community found on Vona loamy fine sand is comparable to that occurring on Dalhart loamy fine sand. For this reason it is essential that comparisons of native plant communities be based on comparable soil types rather than solely on comparable soil series. Plant communities having the most features in common occur on comparable soil types of closely related series.

The range of occurrence of some soil series and types may encompass a change in climate great enough to result in a sufficient change in herbage production and plant composition to have significance in management and use. Thus the nature of the characteristic plant community may change to some degree for soil types having relatively extensive areas of occurrence. Such variations in plant community potential can be identified by recognizing climatic phases of such soil types. Similarly, the stony phases of certain soil types may sufficiently influence soil moisture relationships to produce a recognizably different plant community.

The impact of accelerated erosion on native plant communities is variable for different kinds of soil. Severe erosion of some soil types markedly changes their potential for plant growth and, therefore, changes the kind of plant community found on them as compared to relatively uneroded areas.

Effect of Climatic Gradation on Plant Communities of Closely Related Soils

While soil is but one of the environmental factors determining the nature of native plant communities, it is apparent that the influence of climatic change on plant communities can most effectively be evaluated by comparisons based on a sequence of closely related zonal soils along the line of a climatic gradation. At any point along such a line,

Table 1. Sequence of Native Plant Communities on Closely Related Soils from a Subhumid to a Semiarid Climate in the Southern Plains.

Soil Series and Type	Location	Climate	Soil Characteristics	Characteristic Plant Community
Newtonia silt loam	Eastern Oklahoma	Moist subhumid Annual ppt. 40″ PE Index 70.	Zonal Reddish Prairie soil on gently rolling uplands; moderately acid; "A" horizon silt loam, "B" horizon silty clay loam; underlain by limestone and shales.	Tall grass aspect dominated by big bluestem and little bluestem. Indian grass and switchgrass important secondary species.
Norge silt loam	East Central Oklahoma	Moist subhumid Annual ppt. 35″ PE Index 56.	Zonal Reddish Prairie soil on gently rolling uplands; slightly acid; non-calcareous to 6 feet plus; "A" horizon silt loam, "B" horizon clay loam; underlain by calcareous old alluvium.	Dominated by mid grasses with little bluestem the major species, big bluestem an important secondary species; minor amounts of Indian grass and switchgrass.
St. Paul silt loam	West Central Oklahoma	Dry subhumid Annual ppt. 27″ PE Index 42.	Zonal Chestnut soil on nearly level uplands; neutral to mildly alkaline reaction; calcareous below 30 inches; "A" horizon silt loam, "B" horizon silty clay loam; underlain by calcareous silty clay.	Dominated by blue grama; side oats grama is a significant mid grass component; buffalo grass a secondary species; little bluestem a minor component.
Richfield silt loam	Oklahoma Panhandle	Dry subhumid Annual ppt. 19″ PE Index 27.	Zonal Chestnut soil on nearly level uplands; weakly alkaline; calcareous below 20 inches; "A" horizon silt loam; "B" horizon silty clay loam; underlain by strongly calcareous silt loam materials.	Definite short grass aspect dominated by a mixture of blue grama and buffalo grass, mid grasses rare or lacking.
Baca silt loam	Southeastern Colorado	Semiarid Annual ppt. 14″ PE Index 25.	Zonal Brown soil on undulating uplands; mildly alkaline; highly calcareous below 10 inches; "A" horizon silt loam to silty clay loam; "B" horizon heavy clay loam; underlain by silt and clay loess-like materials.	Short grass aspect dominated by blue grama with buffalo grass as the principal secondary species; small amounts of galleta grass *(Hilaria jamesii)*. Substantially less total plant cover.

FIGURE 1. Upland plant community dominated by tall grasses on zonal Reddish Prairie soils in northeastern Oklahoma.

the plant communities of associated azonal and intrazonal soils and also zonal soils of different texture may differ more than widely separated plant communities of closely related zonal soils.

Observations of plant communities on closely related zonal grassland soils of similar texture extending from a moist subhumid climate in eastern Oklahoma to a semiarid climate in southeastern Colorado and northeastern New Mexico, reveal a gradual transition from a plant community dominated by tall grasses to a plant community dominated by short grasses (Table 1).

This sequence of zonal soils includes Newtonia silt loam, Norge silt loam, St. Paul silt loam, Richfield silt loam, and Baca silt loam. Newtonia and Norge are Reddish Prairie soils, St. Paul and Richfield are Chestnut soils, and Baca is a Brown soil. Texture of the "A" horizons is silt loam, while that of the slowly permeable subsoils is silty clay loam. Climate is moist subhumid with an annual precipitation of 42 inches and a PE index of 70 in the area of occurrence of Newtonia silt loam with a gradual transition to a semiarid climate, 14 inches annual precipitation, and a PE index of 26 in the area of Baca silt loam.

The plant community of Newtonia silt loam has a tall grass aspect due to the abundance of big bluestem *(Andropogon gerardi)*. Little bluestem *(Andropogon scoparius)* is the most important associated species. Indian grass *(Sorghastrum nutans)* and switchgrass *(Panicum virgatum)* are important secondary species (Figure 1). Little bluestem is the dominant species on Norge silt loam. Big bluestem is a secondary species. Indian grass and switchgrass are minor components (Figure 2). St. Paul silt loam is dominated by blue grama with side oats grama as an important associated species and little bluestem a minor secondary species. Richfield silt loam is dominated by blue grama with buffalo grass as the major associated species. No significant amounts of mid grasses occur on this soil (Figure 3). Baca silt loam is overwhelmingly dominated by blue grama with buffalo grass as a secondary species. Galleta grass *(Hilaria jamesii)* occurs as a minor secondary species.

FIGURE 2. Characteristic plant community dominated by mid grasses on zonal Reddish Prairie soils in central Oklahoma.

FIGURE 3. A short grass plant community on zonal Chestnut soils in the semiarid High Plains.

A gradual transition from plant communities dominated by tall grasses eastward and short grasses westward is not apparent if the sequence of closely related zonal soils is ignored. Plant communities with significant tall grass components extend to a semiarid climate on certain alluvial soils. Similarly, upland plant communities with significant tall and mid grass components occur westward in the High Plains on some deep sandy soils, and those deep stony soils which concentrate soil moisture. Plant communities with significant short grass components extend eastward into subhumid climates on some Planosols and some Lithosols.

An example of a contrast at a point along the line of this climatic gradation on soils of comparable surface texture is found in central Oklahoma on Norge silt loam and Kirkland silt loam. The latter soil is an intrazonal Planosol. As contrasted to the mid and tall grass community on the zonal Norge silt loam, the plant community on Kirkland silt loam supports significant amounts of blue grama and buffalo grass. Mid grasses, principally side oats grama and little bluestem, are secondary species. Tall grasses are sparse or lacking. Failure to recognize the difference in potential of these two soils would erroneously attribute the difference in plant communities to variations in range condition.

Use of the Soil Survey in Determining Range Sites

In the Soil Conservation Service, range conservationists and soil scientists work together to determine the kinds of soil that are included in a range site and to establish soil mapping legends for rangeland in which the boundaries of mapping units can be used to determine the boundaries of range sites. Soil survey reports include a brief description of the range sites within the survey area, a listing of the soils included in each site, and the identification of the site or sites associated with each soil mapping unit.

The number of soil series, types, and phases within a single range site is variable. In the Southern Plains most range sites in current use include approximately two to six soil types of one to four soil series. In a few instances a range site is limited to a single series and type.

Summary

1. The nature of the relationship between kinds of soil and kinds of native plant communities is becoming more apparent as a result of joint field evaluations by soil scientists and range conservationists in connection with the National Cooperative Soil Survey.
2. Higher soil classification categories aid in making broad generalizations about extensive native plant communities. They lack the specificity needed to identify specific local areas of rangeland having potentials for producing essentially similar native plant communities.
3. The most meaningful correlation between kind of soil and kind of native plant community occurs at the soil type and soil phase level of differentiation.
4. Variations in plant communities associated with climatic gradients are best determined by comparisons of characteristic plant communities on similar soil types of closely related soil series.
5. Recent soil survey reports of areas including privately owned rangelands list the soils included in range sites and identify the range sites delineated by individual soil mapping units.

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Chemical Properties and Moisture Extraction in Rangeland Soils as Influenced by Nitrogen Fertilization[1]

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Fertilization of native rangeland has been studied in the Great Plains area for only the past 13 years. During this period several investigators (Klipple and Retzer 1959, Lodge 1959, McIlvain and Savage 1950, Rogler and Lorenz 1957, and Westin, Buntley, and Brage 1955) reported increased herbage production as a result of nitrogen fertilization. Changes in botanical composition with nitrogen fertilization have been observed in some studies. These investigators made no mention, however, of the effect of nitrogen fertilizer on chemical properties of the soil and the moisture withdrawal pattern.

It has been found that fertilizer materials leave a residue in the soil which may be acidic, basic, or neutral. Pierre (1933) stated that nitrogen fertilizer compounds containing the ammonium form of nitrogen will ultimately increase soil acidity. He reported that ammonium sulfate, ammonium phosphate, ammonium nitrate, and urea all increased soil acidity while sodium nitrate, calcium nitrate and calcium cyanamide decreased soil acidity (Pierre 1928). Wander (1954) reported that after 12 years of fertilization with equivalent amounts of nitrogen as ammonium sulfate and sodium or potassium nitrate, the soil was considerably more acid under the ammonium treatment than under the nitrate treatment to a depth of 6 feet. He also found that on plots limed for pH control in the surface soil, the subsoil was considerably more acid where the ammonium form was used than where the nitrate form had been applied.

The effect of pH on the availability of soil phosphorus has been illustrated by Burd (1948) and Gardner and Kelley (1940). In these investigations minimum phosphate solubility occurred near pH 7.0 but increased at higher or lower pH values.

An investigation to evaluate the effects of fertilization of native rangeland was initiated at the Northern Great Plains Field Station, Mandan, North Dakota in 1951. A report on the vegetative aspects of this investigation was made by Rogler and Lorenz (1957). The objectives of the studies reported here were to evaluate the influence of 9 applications of nitrogen fertilizer on (1) the chemical properties of the soil and (2) the moisture extraction pattern of native range.

Methods and Materials

Five by 20-foot plots of mixed native grass on soil classified as Eakin silt loam were fertilized annually for 9 years with 0, 30, and 90 pounds of nitrogen per acre as ammonium nitrate. The dominant species of the area at the beginning of the study were blue grama *(Bouteloua gracilis)*, western wheatgrass *(Apropyron smithii)*, and needle-and-thread *(Stipa comata)* grasses and thread-leaf-sedge *(Carex filifolia)*.

Each treatment was replicated 3 times. Soil Samples for chemical analysis were collected in October 1959 in 6-inch increments to a depth of 2 feet and in 1-foot increments from 2 to 6 feet. Samples were not taken when the experiment was initiated, but it is assumed that all plots were equal in nitrogen, phosphorus, and pH at the beginning of the study. Three soil cores from different locations within each plot were composited to make a sample. Samples were air dried and rolled to pass a 2 mm sieve. Laboratory analyses included total nitrogen, available phosphorus, and pH as determined by Kjeldahl (Association of Official Agricultural Chemists 1955), sodium bicarbonate extraction (Olsen, Cole, Watanabe, and Dean 1954), and saturated paste (United States Salinity Laboratory Staff, 1954) procedures, respectively.

Soil samples for moisture determinations were started in 1954, 3 years after the experiment was initiated. Samplings were made by 1-foot increments to a depth of 6 feet in May or early June and October. Two cores in each plot were composited for one sample. The amount of moisture present in each sample was determined gravimetrically.

[1] *Contribution from Soil and Water Conservation Research Division, and Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture.*

Results and Discussion

Nitrogen

Total soil nitrogen determinations (Table 1) indicate that for the overall 6-foot depth there was a general increase in soil nitrogen with increasing nitrogen fertilizer rates. Significant increases over the no-fertilizer treatment occurred in the first and second depths with 30 pounds of nitrogen and highly significant increases occurred in the same depths with 90 pounds of nitrogen. Within the 6-foot depth, however, some increments showed a decrease with fertilizer. There was a significant decrease in the 24- to 36-inch increment under the 30-pound nitrogen treatment and a highly significant decrease in the same increment under the 90-pound nitrogen treatment. These decreases are attributed to increased root activity in the lower depths.

Nitrogen applied during the 9-year period totaled 270 and 810 pounds for the 30- and 90-pound treatments, respectively. The overall soil nitrogen increases of 240 and 560 pounds per acre account for only 88.9 and 69.1 percent of the total nitrogen applied in the 30- and 90-pound treatments, respectively. When the nitrogen content of the herbage attributed to the fertilizer was totaled for the 9-year period and added to the increase in nitrogen in the soil, all of the nitrogen applied in the 30-pound treatment and 87.9 percent of the applied in the 90-pound treatment was accounted for.

Soil pH

Nine annual applications of 30 pounds of nitrogen per acre, changed surface soil (0 to 6 inches) pH from 6.5 to 6.1 (Table 2). This was an increase in acidity of 6.2 percent (significant at 0.05 level) over that of the non-fertilized plot. With 9 applications of 90 pounds of nitrogen, soil acidity in the same soil increment was increased by 9.2 percent (significant at 0.01 level). Tables 1 and 2 reveal that statistically significant soil acidity increases and total nitrogen increase occurred in the same depth increments. Inasmuch as ammonium nitrate is an acid-forming material small changes in pH would logically be expected. Throughout the profile where total nitrogen increases were small or non-existent, pH remained constant irrespective of fertility treatment.

Available Phosphorus

When surface soil acidity increased, corresponding increases in available phosphorus were found (Table 3). The increase, however, was significant (0.05 level) only under the 90-pound application rate. Below 12 inches, available phosphorus fluctuated within depths and in general decreased where fertilizer had been applied. These decreases were significant in only the 18- to 24- and 60- to 72-inch increments. Some of the decrease within these lower depths may have been due to natural soil variability but can probably be attributed to increased root activity.

Table 1. Total soil nitrogen in native grass plots fertilized annually for a 9-year period.

	Nitrogen Applied		
Depth	0	30	90
Inches	(Pounds per acre)		
0-6	5400	5820*	6020**
6-12	2940	3040*	3200**
12-18	2140	2140	2220
18-24	1580	1580	1580
24-36	2200	1920*	1880**
36-48	1320	1320	1240
48-60	1080	1080	1080
60-72	1040	1040	1040
Sum	17700	17940	18260
Increase		240	560

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

Moisture

During the last 6 years of the study the effect of nitrogen fertilizer on soil moisture was determined (Figure 1). Since fertilization was started 3 years prior to the initiation of moisture sampling, soil moisture differentials due to fertilizers undoubtedly had already been established, especially in the lower 4 depths. Throughout the sampling period yearly soil moisture fluctuations in the first and second foot depths were due to the relation of sampling time to precipitation. It would be expected that spring moisture in the first foot of soil would be similar under all treatments. However, since spring samples were taken in late May or early June, growth had already started and fertilized grasses made a greater early spring growth.

Haas (1958) found that weight of grass roots throughout a 6-foot depth was increased by nitrogen fertilizer applications of 90 pounds per acre. Hunter and Kelley (1946) found that roots can absorb moisture and nutrients from moist soil and depths of 4 feet and transport them through soil at or below the permanent wilting point to the plant top. During the sampling period soil moisture in all depths under the 30- and 90-pound nitrogen treatments was lower than where the grass had not been fertilized. This indicated root activity. Through the 1957 sampling period there was a general decrease in soil moisture within sampling depths of all treatments. After that time very

Table 2. Soil pH as influenced by nitrogen fertilization.

Depth	Nitrogen Applied 0	30	90
Inches	— — — — (Pounds per acre)	— — — —	
0-6	6.5	6.1*	5.9**
6-12	6.6	6.6	6.4
12-18	6.7	6.7	6.7
18-24	7.2	7.2	7.2
24-36	7.6	7.6	7.6
36-48	7.9	7.8	7.9
48-60	7.9	7.9	7.9
60-72	8.0	7.9	8.0

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

Table 3. Available phosphorus in native grass plots fertilized annually for 9-year period.

Depth	Nitrogen Applied 0	30	90
Inches	— — — — (Pounds per acre)	— — — —	
0-6	27.99	29.33	31.32*
6-12	13.16	13.21	13.29
12-18	12.80	10.99	10.89
18-24	11.06	8.95**	9.80**
24-36	9.38	7.21	7.01
36-48	6.66	6.31	6.55
48-60	6.27	6.58	5.44
60-72	10.44	8.94*	7.80**
Sum	97.76	91.52	92.10

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

little change occurred under any treatment except in the first 2 feet of soil. It is believed that as the fertilized plants needed moisture not supplied by precipitation, root growth was stimulated into the moist soil of the deeper depths and resulted in greater moisture withdrawal. As previously pointed out, the decrease in total nitrogen and available phosphorus content in some of the deeper increments further indicated increased root activity in those depths.

Summary

Ammonium nitrate was applied annually during 9 years at rates of 0, 30 and 90 pounds of nitrogen per acre to native range plots. At the end of this period total soil nitrogen, available phosphorus, and pH determinations were made. During the last 6 years, spring and fall soil moisture determinations were made to evaluate the effect of fertilization on soil moisture withdrawal.

For the overall 6-foot depth there was an increase in total soil nitrogen. Increases occurred in the first 2 depths under both the 30- and 90-pound treatments. Some decrease occurred, however, in the 24- to 36-inch increment under both treatments. These decreases were possibly the result of increased root activity within these depths.

The increases in total soil nitrogen accounted for 88.9 percent and 69.1 percent of all the nitrogen applied in the 30- and 90-pound treatments, respectively, during the 9-year period. With the addition of the fertilizer nitrogen recovered in harvested herbage, a complete account of the 30-pound applications and 87.9 percent of the 90-pound applications was made.

In the 0- to 6-inch surface increment soil acidity was increased 6.2 and 9.2 percent by the application of 30 and 90 pounds of ammonium nitrate nitrogen, respectively.

Phosphorus availability in the surface soil increased with in-

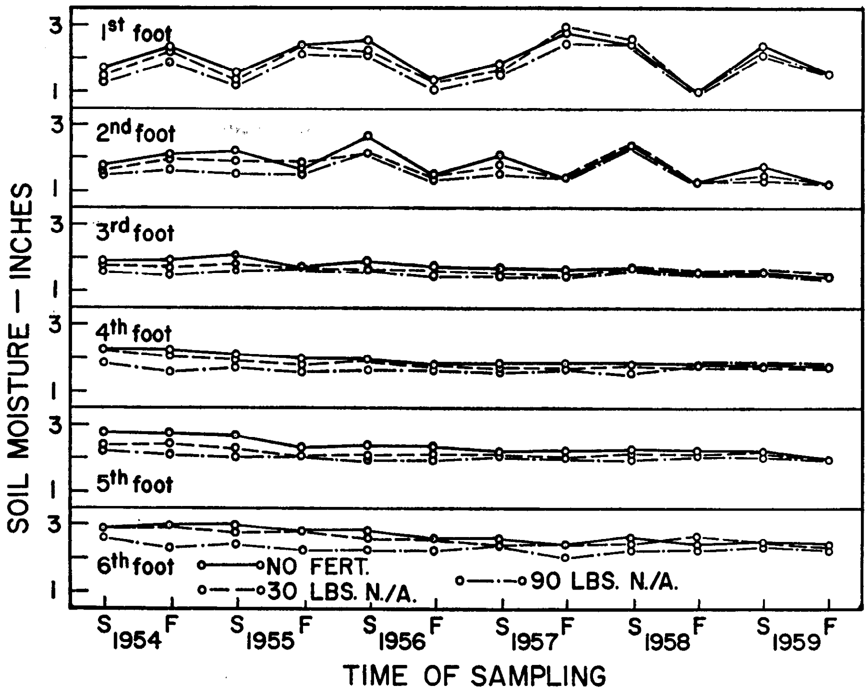

FIGURE 1. Effect of nitrogen fertilizer on spring and fall soil moisture extraction by native grass.

creasing nitrogen rates. Increase in soil acidity was the determinant of the increased phosphorus availability. Less available phosphorus was present in the lower portion of the profile where nitrogen fertilizer had been applied. This was attributed to increased root activity in the lower depths.

Moisture withdrawal increased in all soil depths with the addition of nitrogen fertilizer. Greater moisture extraction accompanied greater fertilization rates. However, after 1957, there was little change in moisture withdrawal under any treatment. In the early years of the study there were indications that fertilization stimulated root growth and moisture use in the subsoil.

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Effects of Clipping Treatments and Clonal Differences on Water Requirement of Grasses[1]

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One factor of fundamental importance to grass improvement is the reaction of the individual grass tillers to clipping under various conditions including moisture levels. This would help explain the relation between the stage of growth and defoliation as well as the reaction of the plant to soil moisture levels.

Review of Literature

Ellett and Carrier (1915) studied the effect of defoliation on composition and total yield of some grasses. They found that frequent defoliation decreased the yield of dry matter. Also frequent defoliation increased total protein content enough to compensate for the decrease in yield of dry matter. In a similar investigation, Aldous (1930) verified the decrease in total dry matter produced. However, he stated that the increase in total protein was not enough to compensate for the decreased yield.

In a study in Wyoming by Lang and Barnes (1942), the grasses were divided into short and midgrasses. Short grasses cut frequently at ground level yielded more dry matter than those not clipped during the growing season. On the other hand, midgrasses cut often yielded less dry matter than those not clipped.

In addition to frequency of clipping, height of clipping is important. Under ordinary grazing conditions, grasses are not cut at uniform levels. The effect of clipping at different levels on crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult) was studied by Cook and Stoddart (1953). In this investigation, the crested wheatgrass plants defoliated below the uppermost node made regrowth from the axillary buds at the base of the culm. On the other hand, if the culms were defoliated above the last node, the shoot continued to develop and elongate. If the culm was cut between the uppermost node

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and the seedhead, elongation continued but the culm remained headless. Plants clipped early in the season above the terminal bud produced normal culms, but they failed to produce leaves. Regrowth did not occur if the plants were closely cut and subjected to arid conditions.

The studies made by Cook and Stoddart suggest another thing to be considered, the stage of growth when defoliated. Experiments concerning stage of growth are usually concerned with hay production but could be of interest in grazing management. A study by Bird (1943) was primarily concerned with the effect of clipping on hay production at various stages of growth. The six stages of growth he compared were short grass, long grass, beginning of heading, beginning of bloom, end of bloom, and following seedset. Total yield of dry matter increased with each successive stage up to the beginning of bloom; thereafter, the increases in dry-matter yields were not significant.

Stoddart (1946) in Utah studied the effect of cutting *Agropyron spicatum* (Pursh) Scribn. Because the area was primarily a spring-fall grazing area, clippings were made in both seasons. Cutting the plants in early spring had a less harmful effect than cutting in late spring. The reason for this being that plants defoliated in early spring had a chance to recover and make regrowth before the dry summer. Clipping in the fall had little detrimental effect on the plants.

Keller (1953, 1954) made two studies of the water requirement of orchardgrass *(Dactylis glomerata* L.). Water requirement was defined as "the ratio of weight of water absorbed by a plant during its growth to the weight of dry matter produced." In the first study Keller (1953) found a significant difference in water requirement among genotypically different strains of orchardgrass. He reported that the higher yielding plants were more efficient in their use of water. The second study (1954) involved techniques of making greenhouse studies on water requirement of orchardgrass. This appears to be an effective method of selecting plants on the basis of their economy of water use, but, as Keller stated, the plants should be tested in the field as well as in the greenhouse before any final selections are made.

Materials and Methods

The clones of grasses used in the investigation were selected on the basis of their leaf width, growth habit, leaf color, and vigor. Three intermediate wheatgrass and two pubescent wheatgrass plants which differed rather widely in the above characteristics were selected (table 1).

Part of each clone to be used in this study was brought into the greenhouse in September, before the plant was subjected to cold. They were allowed to develop under short day length until the experiment was begun. The remainder of the plant was taken from the field in December, after being subjected to several periods of low temperatures. These plants were assumed to have become vernalized.

After greenhouse acclimation, the plants were separated into individual tillers. These were then rooted in sand.

The canisters, to which the tillers were eventually transferred, were prepared next. The canisters were seven inches high and six inches in diameter. The bottom of every container was evenly covered with 450 grams of pea gravel. A glass tube, one-half inch in diameter and approximately seven inches in length, was placed in each. The glass tube stood upright along the side with the base resting on the pea gravel. Next, 3,000 grams of air-dry soil, previously dried by spreading it out in a thin layer on a greenhouse bench, was added to each container. A standard greenhouse soil mixture, on which field water capacity was determined to be approximately 23.5 percent on a dry-weight basis, was used. Therefore, 705 ml. of water was added to every container to bring the moisture content up to field capacity. The canisters were then allowed to stand overnight. The following day, five well-rooted tillers from one clone were planted in each canister. An additional 100 ml. of water was then added to make up for evaporation and to wet the pea gravel. An additional 400 grams of pea gravel added to the top of each canister brought the total weight of each container to 4,955 grams. This top layer served as a mulch to reduce evaporation.

The tillers were allowed to grow and develop for three weeks. Moisture was maintained at about field capacity in all the containers, and the day length was maintained at ten hours. At

Table 1. Clones of intermediate and pubescent wheatgrass selected for studies of effect of defoliation and morphological development on water requirements.

Kind of grass	Clone No.	Variety	Leaf width	Growth habit	Color	Vigor 1-3*
Intermediate wheatgrass:						
	1	S 4904	Medium	Erect	Light green	2
	2	A 12496	Medium	Erect	Light green	2
	3	Mandan 1274	Narrow	Erect	Green	1
Pubescent wheatgrass:						
	4	Loga II	Narrow	Erect	Light green	2
	5	Bismark	Narrow	Erect	Light green	2

*1=most vigorous; 3=least vigorous.

Table 2. Average number of tillers per plant.

Vernalization and water level treatments	Clipping height (inches)	Clone 1	Intermediate Clone 2	Clone 3	Pubescent Clone 4	Clone 5
Vernalized:						
High	2	4.96	6.38	4.33	5.91	8.72
High	4	5.82	10.92	7.75	8.22	7.75
Low	2	2.99	4.42	2.31	3.40	4.31
Low	4	3.50	3.89	3.86	4.80	4.13
Non-vernalized:						
High	2	6.66	8.55	6.92	7.75	6.48
High	4	5.65	10.55	7.97	7.35	9.55
Low	2	3.70	4.43	3.71	4.20	3.35
Low	4	3.81	4.47	3.81	4.29	5.46
Clone means		4.63	6.70	5.08	5.74	6.22

L.S.D. 0.05 level for clone means 0.80

the end of three weeks, all the plants were cut back to two or four inches. The day length was increased to sixteen hours. All the canisters were brought back to a standard weight of 4,955 grams, or field capacity, by the addition of water.

The plants were permitted to grow for another two weeks, after which they were again clipped at two or four inches. The following treatments were then begun:

A. Moisture levels were maintained as follows:
   1. At field capacity
   2. At just above the wilting point
B. Clipping heights at each two-week intervals were as follows:
   1. At a height of two inches
   2. At a height of four inches

The experiment was designed as a randomized block with four replications. Evaluation of the clones was made on the basis of tillering, dry-matter yield, water requirements, and regrowth.

The plants were clipped at two-week intervals. The canisters were weighed and brought back to their corresponding moisture level each week. One-half of the canisters were kept at field capacity, or 4,955 grams, and the other half were kept at just above the wilting point, or 4,555 grams. To determine the weight to be used at the low water level, a canister containing plants was allowed to dry out until the plants started to wilt. Just enough water was then added to prevent the plants from wilting. The canister was then weighed and this weight, or 4,555 grams used for the low water level.

Several checks without plants were maintained at both water levels. They were weighed each week and brought back to field capacity. These checks helped in determination of the amount of water lost by evaporation. The amount of water that had transpired and had been used for photosynthesis and other physiological processes was then calculated for each canister containing plants.

At the end of the study, the numbers of tillers and reproducing culms were counted. The total clippings from the plants in each canister were dried in an oven at 150° F. for twenty-four hours and weighed.

Results and Discussion

Tillering

At the start, five individual tillers were planted in each canister. When the study closed, the tillers in every container were counted (table 2). The number of tillers produced by the vernalized and non-vernalized plants did not differ significantly.

The plants clipped at four inches yielded significantly more tillers than those clipped at two inches. This finding would be expected, as the plants cut at two inches were required to use more of their food reserves for regrowth. The numbers of tillers produced by the different clones differed significantly (table 2).

Dry-Matter Yield

Every two weeks, half of the plants were defoliated at two inches above the surface and half at four inches. All the clippings from the plants in each canister were dried in an oven at 150° F. for twenty-four hours and weighed. The mean weights, expressed in grams, are presented in table 3. The plants which had become vernalized

Table 3. Mean yield of dry matter per pot.

Vernalization and water level treatments	Clipping height inches	Clone 1	Intermediate Clone 2	Clone 3	Pubescent Clone 4	Clone 5	Water level means
Vernalized:		— — — —	— — (Grams)	— — —	— —	— —	
High	2	3.36	2.68	2.95	3.17	2.86	
High	4	3.04	3.90	3.19	2.78	2.39	3.03
Low	2	1.42	1.43	1.38	1.21	1.14	
Low	4	1.22	0.96	1.29	1.00	0.89	1.19
Non-vernalized:							
High	2	3.33	2.92	2.83	2.46	2.56	
High	4	2.83	2.36	2.14	2.51	2.70	2.66
Low	2	1.27	0.96	1.20	0.91	0.74	
Low	4	1.06	0.86	0.88	0.95	0.73	0.96
Clone means		2.19	2.00	1.98	1.87	1.75	

L.S.D 0.05 level for clone means 0.24
L.S.D. 0.05 level for source means 0.22
L.S.D. 0.05 level for clipping height means 0.11
L.S.D. 0.05 level for water level X source means 0.08

Table 4. Grams of water utilized per unit of herbage produced.

Vernalization and water level treatments	Clipping height (inches)	Clone 1	Intermediate Clone 2	Clone 3	Pubescent Clone 4	Clone 5
Vernalized:						
High	2	97.08	172.42	116.50	159.67	252.60
High	4	221.65	355.77	188.53	220.18	228.76
Low	2	72.53	72.71	71.37	79.07	78.40
Low	4	116.73	84.04	107.96	116.77	153.62
Non-vernalized:						
High	2	151.65	196.47	197.55	120.37	239.50
High	4	241.74	238.95	212.17	249.34	280.23
Low	2	88.99	123.95	81.59	82.05	62.49
Low	4	112.94	129.19	89.87	134.83	144.84
Clone means		137.91	171.59	126.44	145.28	180.05

L S.D. 0.05 level for clone means 25.55

produced a greater amount of dry herbage than the non-vernalized plants. However, toward the end of the study, the non-vernalized plants were beginning to yield as much as the vernalized.

Plants clipped at two inches produced significantly more herbage than did the plants clipped at four inches. These results might have been reversed if the experiment could have been carried on for a longer period. As shown in table 2, the plants clipped at four inches were producing the largest number of new tillers.

Water Used Per Unit of Herbage Produced

The means by weight of water used to produce one gram of air-dry herbage are presented in table 4. These means were computed by dividing the total grams of water used by the total grams of herbage produced. The results obtained from this computation would be a partial measurement of a good dryland forage grass. Theoretically, a desirable dryland grass would be a grass that produces the greatest amount of forage with the water that is available. Although this is only one factor which should be considered, it could serve as one criterion in grass selection.

The plants clipped at two inches were more efficient in their use of water than those clipped at four inches. This difference is probably a result of the greater transpiring area of the plants clipped at four inches. There was no significant difference between the water requirements of the vernalized and the non-vernalized plants. Table 4 shows a significant difference in the water requirements of the different clones. To produce one gram of air-dry herbage, the most efficient clone, 3, had a water requirement of 126.44, while the least efficent clone, 5, had a water requirement of 180.05. Clone 3 was significantly more efficient in use of water than was 5. Pubescent wheatgrass clone 4 and intermediate wheatgrass clone 1 were more efficient in their use of water than clones 2 and 5. Clone 1, yielded the most, was one of the most efficient clones in the use of water, with a water requirement of 137.91 grams per gram of herbage produced.

Summary

The objective of this study was to determine the influence of clipping on the growth of individual grass tillers under drought stress. In the fall of 1958, three intermediate and two pubescent wheatgrass plants were selected from the source nursery located at the Wyoming Agricultural Experiment Station near Laramie. Half of each plant was brought into the greenhouse in September and the remainder in December. These plants were separated into individual tillers and planted in canisters after being rooted in sand. Half of the canisters were maintained at approximately field capacity and the other half were maintained just above the wilting point. The plants were clipped at two and four inches above the soil surface. Evaluation of the clones was made on the basis of tillering, dry-matter yield and water requirements.

Differences between the vernalized and non-vernalized plants in their reaction to total water use and dry-matter yield were observed. The results of the study indicate also that height of clipping affected the number of tillers produced, total herbage yield, and water used per gram of forage produced. There were significant clonal differences in the number of tillers produced and in the efficiency of water use.

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Wheel-Track Planting on Sagebrush-Bunchgrass Range

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A new machine that performs wheel-track planting of small-seeded grasses has been designed, contructed, and tested in Oregon.[2] The new seeder, which has been accepted for extensive testing by the Inter-Agency Range Seeding Equipment Committee, will be called the Oregon Press Seeder. The authors take this opportunity to introduce the Oregon Press Seeder and the record of its conception, construction, and preliminary testing.

We wish to acknowledge the support provided by R. M. Alexander, Assistant Director, Oregon Agricultural Experiment Station, for the co-operative project that produced the Oregon Press Seeder. The ideas employed in equipment design and construction were largely original with the authors, but valuable suggestions (unfortunately unrecorded by source) were received from personnel of the Oregon Extension Service, the Bureau of Land Management, and the Forest Service. Consequently, a grateful but anonymous acknowledgement is given.

Seeding Problems And Equipment Conception

Conserving Soil Moisture for Seed Germination

Drought and improper planting depths have long been considered as the two most common causes of seeding failures on semiarid ranges. Attention was directed especially to the problem of retaining moisture longer in the surface seed-depth layer of soil. Thoughts regarding moisture transfer within the soil led to the consideration of soil-density effects as influenced by firming operations. The value of firming for seedling emergence has been easy to demonstrate but remains difficult to define because of the complex interactions obtained. Excessive firming produces detrimental effects that have been studied more than the beneficial effects of moderate firming. But there is no way to separate good or bad effects. Rather the effects are progressive with increasing soil firmness, and the interpertation of good or bad depends upon the objective involved.

The work completed at the Squaw Butte Range in Oregon showed that soil firming increased moisture retention in the surface 2 inches of soil and sustained the moisture content above the wilting coefficient about 4 times as long as in unfirmed soils (Hyder, Sneva, and Sawyer, 1955, Hyder and Sneva, 1956). Soil-moisture content in the surface 2 inches of unfirmed soils remained permanently below the wilting coefficient after 3 days. However, the moisture content in the surface of heavily firmed soils exceeded the wilting coefficient throughout a 12-day study period. The studies also showed that wheel-track firming provided soil moisture longer than firming the entire soil surface. In the case of wheel-track firming, soil-moisture samples were obtained only in the tracks.

A recent Russian paper described firming advantages and established that the total soil-moisture supply was reduced by firming (Yarovenko, 1958). Increased evaporation losses, and subsequently a decreased total soil-moisture supply, were anticipated but not found in the Squaw Butte studies. Soil firming is proposed not to save moisture but to permit more effective use of it, which is moisture conservation in the true sense. Firming to increase surface soil-moisture content provides a practical way to use soil moisture more effectively for promoting seed germination and emergence. One may employ wheel-track firming to obtain moisture benefits along planted rows while holding to a minimum the opportunity for evaporation and the susceptibility for wind erosion.

Firming effects extended beyond the realm of seed-soil relations into that of plant-soil relations. Better plant establishment and survival, wider root distribution, hair roots nearer to the soil surface, and higher herbage yields in the first 2 years were reported from the Squaw Butte studies.

Controlling Planting Depth

Rolling to firm and level the soil surface offered an opportunity to improve depth and uniformity of seed placement as well as to improve seed-soil relations. The mechanical problem

[1] *A contribution from Squaw Butte Experiment Station, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture and the Department of Agricultural Engineering, Oregon State University, Corvallis. Technical Paper No. 1378, Oregon Agricultural Experiment Station.*

[2] *Plans and shop drawings are available at the cost of duplication ($3.60) from the Extension Agricultural Engineer, Department of Agricultural Engineering, Oregon State University, Corvallis, Oregon.*

of placing grass seeds at a proper depth in soft irregular-surfaced seedbeds is often the paramount reason for seeding failure on semiarid range. Depth bands on drill discs are often ineffective unless the soil has been firmed.

Problems in Seedbed Firming Practices

The documentation of soil-firming benefits on certain range soils apparently has given insufficient basis for promoting rolling practices. Some of the reluctance for, and difficulties involved in, adopting rolling practices are as follows:

(a) Conventional small-diameter packers often skid rather than roll on soft, dry seedbeds. Suitable large-diameter rollers are unavailable on the market.

(b) Conventional packers are generally too light for optimum firming. This deficiency is most apparent when seeding upon a dry seedbed, as is often necessary on semiarid range.

(c) The cost of rolling has not been established as a profitable investment. Therefore, the necessity of maintaining low seeding costs causes many people to question the value of rolling.

(d) A flat, firm soil-surface is more subject to wind and water erosion than a rough one.

(e) In the management of native vegetation any increase in soil density is undesirable because of reduced water intake and other effects. Consequently, range personnel have been trained to associate soil firming with undesirable effects and some are unpracticed in associating it with desirable seed-soil and plant-soil relations that should be achieved in range seeding.

Requirements of a Practical Seeder

The practical objective has been to obtain an optimum in beneficial effects (while minimizing undesirable effects) by soil firming in a manner consistent with mechanical and economic limitations. The authors believed that a satisfactory solution could be achieved by designing and constructing a seeder according to the following requirements:

(a) An ideal seeding operation should plant the seed at a uniform and proper depth with firm soil below the seed and less firm soil above.

(b) After plowing for vegetation elimination, the entire job of firming and planting should be performed by a single machine.

(c) Wheel-track planting should provide the best means of obtaining optimum seed-soil relations with a minimum of undesirable effects.

(d) The equipment should produce tracks about 6 inches wide and spaced about 12 inches from center to center. The problem of soil movement and excessive seed coverage should not cause seeding failure with tracks less than 3 inches deep and 6 inches wide.

(e) An equipment weight of about 500 pounds per foot of wheel width generally should produce sufficient soil firmness, but the equipment weight should be subject to change from about 500 to 1,000 pounds per foot.

(f) The equipment should be flexible so that each row-planting unit would pass independently over an irregular seedbed.

(g) The equipment should plant 10 or 12 rows simultaneously.

(h) The equipment should require a minimum of adjustment, observation, maintenance, and repair, and must be durable enough to encounter boulders and brush without impairing the planting mechanism.

Seeder Design, Construction, And Testing

Two different seed-placement mechanisms were proposed, as follows: (a) Form and weld a V-shaped angle-iron rib with a vertical height of 1 inch around the center of a press wheel face. Thus, the wheel tread would press a V-shaped seed groove in the wheel-track center. A drag chain or plate would be used to cover the seed. (b) Attach cup-shaped cleats to the face of a press wheel. As the wheel rotated seed would be metered into the cups. The cups, in turn, would make depressions in the bottom of the wheel track and deposit the seed as the wheel continued to rotate. A drag would be used to cover the seed.

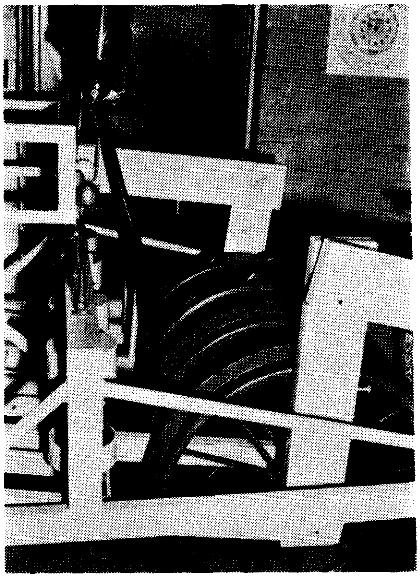

FIGURE 1. Model I was constructed in 1956 to evaluate ribbed and cleated press wheels.

Model I Construction And Performance

Model I, a 4-row seeder, was built in 1956 to evaluate the two mechanisms proposed (Figure 1). In the pilot model, 2 wheels were equipped with cup-shaped cleats and 2 with V-shaped ribs. The wheels were 32 inches in diameter and had a face width of 6 inches. Twelve-inch wheel spacing was used. Individual suspension of the wheels permitted operation on rough ground and over rocks and brush. The machine weight of 1,200 pounds was transmitted to the press wheels through coil springs of the type used in automobile front suspension.

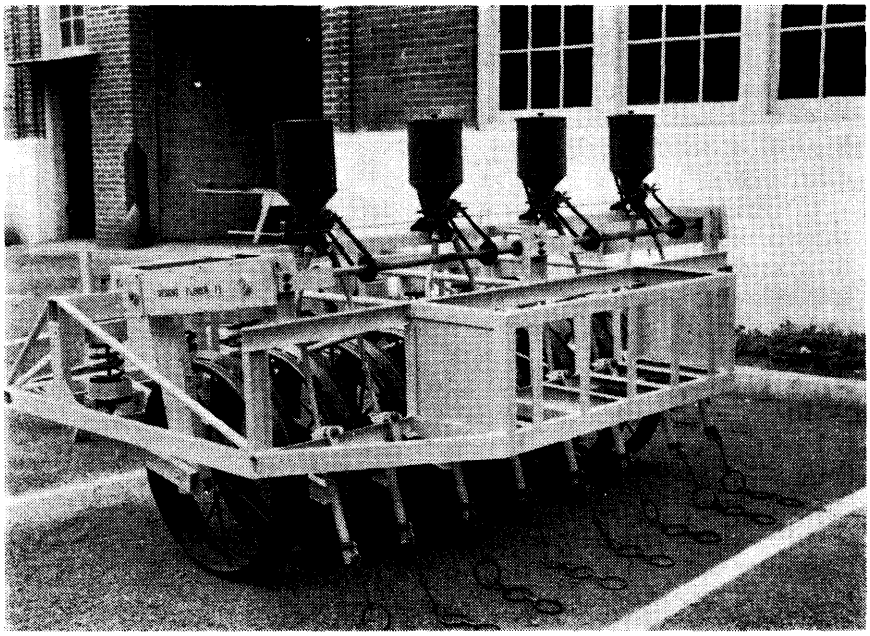

FIGURE 2. Model II, an 8-row machine weighing 2,600 pounds, was constructed and tested on different soils in 1957.

Cleated wheels were unacceptable because the seed were deposited at the front edge of cleat depressions and drag chains pulled the seed to the soil surface. The wheels with V-shaped ribs performed satisfactorily and were chosen for further development.

Model II Construction And Performance

Model II, an 8-row machine weighing 2,600 pounds, was constructed in 1957 (Figure 2). Seeding trials were established at 12 locations in central and southeastern Oregon during the fall 1957. The seeding trials provided opportunity to observe seeding action on different soils that had been prepared for conventional seeding operations. The primary purposes of the trials were to learn to use the equipment properly and discover ways for improving the seeding action. A secondary purpose was to compare seeding results on trial plots with those obtained on the fields seeded with conventional equipment.

The seed were dropped through closely wound plow-lift coil springs clamped to the rear frame member in alignment with the press wheels. The coil springs served as flexible but durable seed tubes. Two difficulties were encountered with the seed tubes: (a) cross winds moved the seed to the side where they were not covered, and (b) the seed tubes sometimes dropped into the soil and became plugged. Subsequently, rubber sleeves were placed on the lower ends of the coil springs to eliminate both difficulties. The rubber sleeves were cut into strips from the bottom upward to about 1 inch below the coil spring outlet. Two-inch wide clamps served as attachment for drag chains, held the rubber sleeves in place, and, by extending below the coil-spring outlet, prevented cutting the rubber sleeves as the seed tubes contacted rocks, brush, and soil.

Standard grain-drill drag chains, attached to the lower end of the seed tubes, covered the seed adequately only when the soil was dry and loose. The seed grooves were not closed in moist soil (Figure 3). Consequently, many different cover drags were tested. Good seed covering was obtained with drags made from ½-inch steel plate cut with a 4-inch width, a 7-inch length, and a tapered front end. Short pieces of rod were welded on the drag faces as an open V to move soil toward the center for seed coverage. Speed of operation was not critical, but with speeds above 5 miles per hour tandem pairs of cover drags were needed to improve drag follow and obtain seed coverage.

The seed hoppers used on the test model gave some difficulty with crested wheatgrass, which was planted in all but one trial. Pubescent wheatgrass was planted in one trial, but the metering device was inadequate. Thus, the seed hoppers were replaced with a standard grain-drill-box.

Additional weights were placed on the machine to obtain distinct wheel tracks and good seeding action on crusted seedbeds. Short pieces of railroad iron were placed in boxes constructed upon both front and rear frame members to maintain equipment balance. The range in gross weight used was 325 to 450 pounds per wheel.

Model II Seeding Results

Seeding rates of crested wheatgrass were 5 pounds per acre with the Oregon Press Seeder

FIGURE 3. Seed furrows in moist soil were not closed by ordinary drag chains.

Table 1. Seeding results with the Oregon Press Seeder and with conventional methods at 12 locations in central and southeastern Oregon.

Soil condition and type	Oregon Press Seeder Density[a]	Conventional seeding Density[a]	Conventional seeding Planting method	Remarks
Very soft, moist sandy loam	1.9	0.1	Rangeland drill	Strong wind erosion after seeding.
Very soft, moist sandy loam	1.1	0.5	Broadcast, log chain drag	Heavy jackrabbit damage.
Soft, dry sandy loam	0.9	0.4	Broadcast, log chain drag	Heavy jackrabbit damage.
Firm, moist sandy loam	4.7	1.5	Commercial single-disc drill	No special difficulties.
Firm, moist sandy loam	2.4	0.8	Commercial single-disc drill	No special difficulties.
Firm, moist sandy loam	2.6	3.8	Rangeland drill	No special difficulties.
Firm, moist very sandy loam	1.4	....	None	Much volunteer rye.
Firm, moist gravelly sandy loam	3.7	1.8	Commercial single-disc drill	Reseeding without new tillage.
Hard, dry gravelly sandy loam	0.5	1.1	Broadcast, log chain drag	Heavy jackrabbit damage.
Hard, moist gravelly sandy loam	0.4	0.3	Rangeland drill	Heavy jackrabbit damage.
Hard, gravelly clay loam	b	b	Rangeland drill	Very heavy volunteer rye.
Wet, red clay loam	0.1	1.2	Rangeland drill	Pubescent wheatgrass seeding.

[a]Number of seedlings per square foot.
[b]Unsampled because of thick volunteer rye.

and about 6 pounds per acre with conventional equipment except a commercial single-disc grain drill, which seeded about 4 pounds per acre. Trial plots included 3 to 5 acres on each field. Seeding results were evaluated by density counts in the summer 1958. Average stand densities are presented in Table 1.

The improvements needed for cleaning wheels, placing seed in seed grooves, and covering the seed were not completed during the seeding trials. Nevertheless, excellent stands of crested wheatgrass were obtained on all trials except those subjected to heavy jackrabbit damage. Seeding was generally more successful on trial plots than on adjacent areas seeded by conventional methods. Differences were most striking on fields with very soft seedbeds at planting time because conventional drilling failed on such seedbeds. On firm or crusted seedbeds both conventional drilling and wheel-track planting were successful. The single trial with pubescent wheatgrass on a wet clay loam was a failure, but conventional drilling was successful. In that case the seeding failure with the Oregon Press Seeder was attributed to the following factors: (a) the seed hoppers did not meter the seed properly, and (b) wet soil collected on wheel faces and prevented the pressing of seed grooves.

Model III Construction And Performance

Model III, an 8-row machine weighing about 3,500 pounds (Figure 4), was released in the fall 1958 for field seeding operations by the Bureau of Land Management personnel in Oregon and Nevada. Those opera-

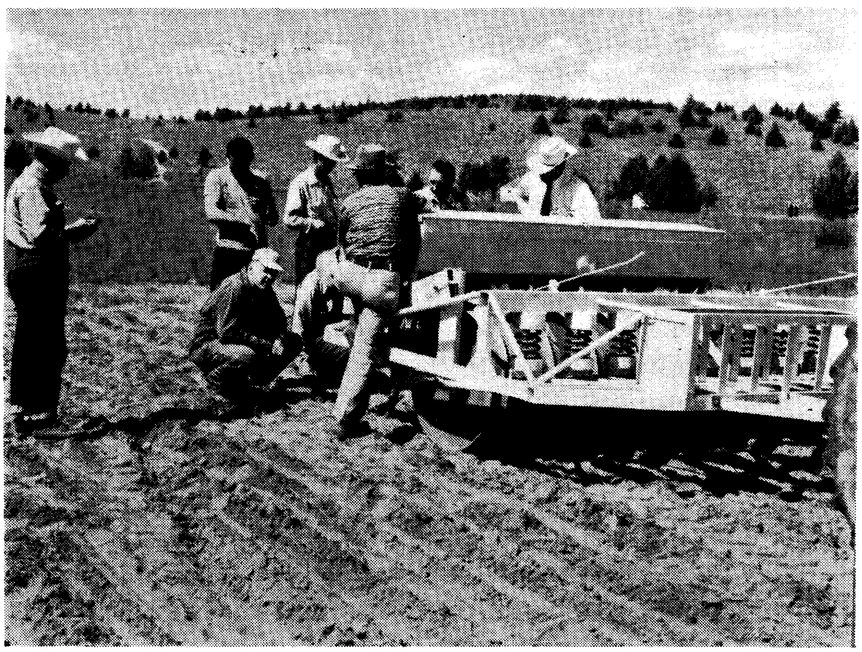

FIGURE 4. Model III was tested on field seeding operations in 1958.

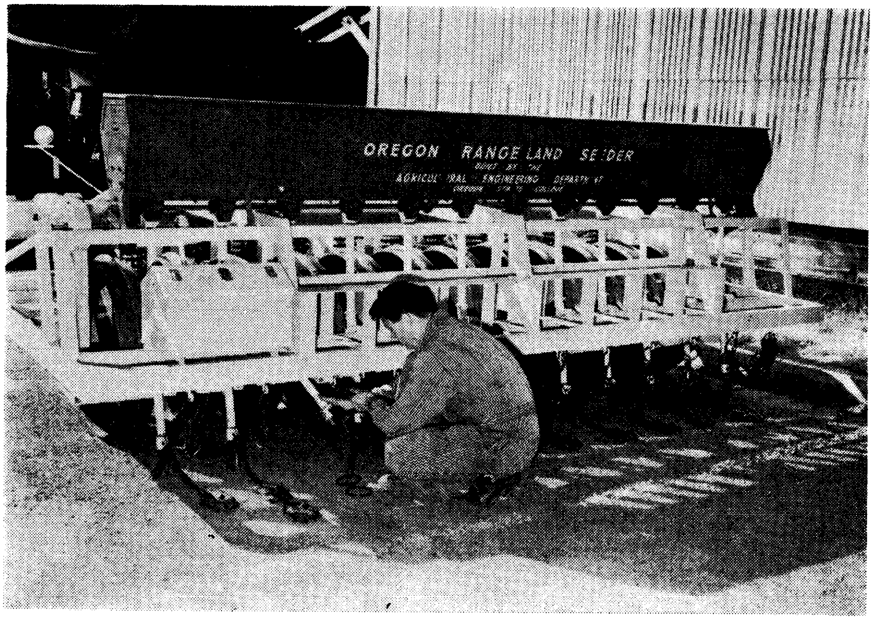

FIGURE 5. Model IV, a 12-row machine weighing 5,000 pounds, was built and tested under field seeding conditions in 1959. The name has been changed to Oregon Press Seeder.

tions provided information about structural weaknesses, maintenance requirements, and personnel reactions. Slight twisting of the wheel-support arms was the only indication of structural weakness. Maintenance requirements were much less than with conventional grain drills, but the loosening of set screws in seed-box drive gears caused some delay. Since the planting mechanism functioned uniformly without continuous attention and adjustment, the field personnel were enthusiastic about the machine operation and the soil-firming principles upon which it was developed. The following proposals were made for improving the seeder: (a) strengthen the press-wheel support arms, (b) install sealed bearings in press wheels, and (c) increase the machine size to plant 12 rows simultaneously.

Model IV Construction And Performance

Model IV, a 12-row machine weighing about 5,000 pounds (Figure 5), was built in 1959 and released to Bureau of Land Management personnel for testing under field conditions. Operational failures were minor. Throughout the seeding trials and field operations it appeared that the objective of trouble free operation had been fulfilled.

The weight of Model IV, about 415 pounds per wheel (6 inches wide), was near the maximum desired wheel load of 500 pounds. It was believed desirable to have a minimum wheel load near 250 pounds to prevent excessive track depth, soil sloughing, and too-deep seed placement in very soft seedbeds. Operational loads with Model II were varied from 325 to 450 pounds per wheel in order to obtain adequate track depths. Consequently, it is desirable to reduce the machine weight of Model IV to about 4,000 pounds—330 pounds per wheel.

Plans and shop drawings were released by Oregon State University to interested parties in January 1960. Further testing and development will be supervised by the Inter-Agency Range Seeding Equipment Committee.

Summary

A planting machine that will operate satisfactorily on soft, plowed seedbeds, which often cause seeding failures with conventional seeders, has been developed in Oregon. The planting mechanism, designed to produce a specific seed-soil relation found desirable in basic research, is a simple and direct fulfillment of wheel-track planting. The machine largely eliminates the problem of planting depths and obtains approximately an optimum seed-soil relation for assurance of successful germination, emergence, and survival of crested wheatgrass. The new seeder, which has been accepted for testing by the Inter-Agency Range Seeding Equipment committee, will be called the Oregon Press Seeder.

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BOOK REVIEWS

Edited by Lowell K. Halls, Forest Service, U. S. Department of Agriculture, New Orleans, Louisiana

Wild Life in an African Territory. By F. Fraser Darling. *Oxford University Press, New York, New York. 160 pages. 1960. $4.00.*

This well-written and nicely published account of a comprehensive ecological reconnaissance of Northern Rhodesia will be both interesting and enlightening to conservationists, land managers, students, wildlife technicians, and all those concerned with the vanishing hordes of wild animals or with the future welfare of Africa.

The author reports on serious situations, and explains that Africa is a continent of immense interest to the ecologist in that waste of natural resources is continuing through extraordinary irresponsibility and ineptitude in a country of unique variety and complexity. The opinion is put forward that the terrain itself has suffered such degradation in the past century by changes in vegetational patterns and erosion that the present biological potential is seriously impaired.

In 1900, the author states, the herds of ungulates represented a natural resource of sufficient abundance which, if cropped efficiently, could have provided an adequate protein diet for all the 60,000 human inhabitants in the Territory. Since then, the human population has increased more than three fold; the herds of wild ungulates have been reduced to a dubious fraction; and the habitat itself has degenerated to a place where the herds of former days could not be sustained now.

The interplay of man and wildlife upon their environment is described through the author's narration of three field trips, involving a total of six months at three seasons, throughout the territory. Darling's observations, impressions, and discusssions of the things he noted are presented in a manner that provides the reader a firsthand commentary of the scope of the field trips.

The journey notes are supplemented in following chapters with ecological descriptions of the habitats encountered, implications of the incidence of fire, ecology of biological communities, conservation of various species of animals, and the organization of national parks, game reserves, and controlled areas. Conclusions and a seven-point schedule of recommendations are included in a final chapter. Relevant directives and a summary of the present day status of the territory's ungulates are included in the appendix.

Continuing wasteful use of the land and its resources is the thesis of this essay. These wasteful uses are discussed in view of their origin, potential continued occurrence, and possible remedial action. Northern Rhodesia's biological capacity is seriously impaired, the author believes. This is unfortunate because of the extreme need of the people for proteinaceous food. Darling speculates that the diversity of wild ungulates would provide a source of protein for Northern Rhodesians for many years, but to have this resource and to make optimum use of it, will require that modern game management practices be employed. This should include immediate steps to halt the disruptive and abusive practices which continue to alter lands used by the ungulates and make them unsuited for the animals' requirements. To exchange the wide spectrum of African ungulates "living in delicate adjustment to the poor and tender habitat, for the narrowed spectrum of three ungulates exotic to Africa — cattle, sheep, and goats—is to throw away a bountiful natural resource and a marvelous ordering of nature," Darling declares.

WILD LIFE IN AN AFRICAN TERRITORY has a value which goes beyond a stimulating and worthwhile presentation of that territory's ecological situation. It illustrates that Africa is a continent in change. The book is helpful for its documentation and analysis of the circumstances and practices believed responsible for the gross ecological conditions in which the territory's ungulates now are a part. The absence of record keeping in the past limits the assessment that can be made, a condition that the author realizes. This report will serve as a benchmark against which to judge the changes, for better and for worse, which undeniably will come about in the future.—*C. R. Gutermuth,* Wildlife Management Institute, Washington, D. C.

Biological and Chemical Control of Plant and Animal Pests. Edited by L. P. Reitz. *Publication No. 61 of the American Association for the Advancement of Science, Washington, D.C. xii + 273 pages. 1960. $5.75.*

This volume consists of 19 papers by a diverse group of chemists and biologists who are concerned either with managing particular organic resources or with investigating biological or chemical processes of controlling pests. All emphasize the need for reducing loss to pests as an important way to increase the usable supply or quality of food, timber, and fiber resources. It is stated that the United States would need 120 million fewer acres of cropland to supply our needs if losses to pests were curbed.

The book is divided into three sections: the public's stake in pest control, recent advances in chemical control, and biological control of pests.

The five papers in the first section include one by M. R. Clarkson, who presents the philosophy that exclusion (through quarantine) is paramount, but if a pest becomes established then eradication is a more logical goal than control. It does seem surprising that there was no quarantine of exotic pests in the U. S. until 1912. With modern methods of communication, quarantine problems are much greater today. As to eradication of established pests, Dr. Clarkson adds "if possible." There could be disagreement on whether it is possible to eradicate any pest. Certainly no biologist will disagree with Dr. Clarkson's definition of the ultimate chemical weapon "-a chemical that is toxic only to the pest-."

J. R. Hansbrough discusses the need for control of forest diseases and J. A. Beal the control of forest insects. They cover all aspects of the drain of disease and pests on forest resources, and even include cull trees or trees of poor quality among the pests to be "controlled." Both writers include silvicultural control in their discussion.

E. H. Fisher discusses education in the use of pesticides and B. L. Oser the regulatory control of pesticides. Both state categorically that pesticides are a boon. The articles tell of methods for making pesticide use more efficient, safer, and generally more acceptable. Some space is devoted to documenting suspected cases of pesticide poisoning that probably were due to other causes. This is a familiar theme today. So far as I know, no one doubts that many pesticides are poisonous; but the number of acute intoxications in the use of pesticides recorded in the United States is relatively small compared with the number in certain foreign countries. Another familiar point made is that it takes a lot of money to develop a new pesticide; of course it does not follow that pesticide regulations should be relaxed merely on this account.

Section II covers recent advances in chemical control. G. L. McNew writes about fungicides and bactericides; R. H. Beatty, weed control; J. E. Casida, organophosphorus systemic insecticides; and F. O. Gossett, internal parasites of domestic animals. These articles probe deeply into the biochemistry of pesticides within the target organism. For example, the chemical action of antibiotics is considered in the fungicide paper; the ability of certain weeds to change phenoxybutyric acid to 2,4-D and thus "do themselves in" is a part of the herbicide paper; and antimyiatic action of chemicals given to animals is included in the systemic insecticide account. An interesting program suggested in the parasite paper is the eradication of internal parasites through routine administration of antiparasitic agents, perhaps in the food.

Biological control is an ancient interaction of species populations and includes all presently known means of pest control. The third, and largest, section of the book includes discussions of all the techniques that usually come to mind: pathogens, by J. D. Briggs; parasites and predators, by C. A. Fleschner; breeding resistant strains, by N. F. Waters (animals), E. H. Stanford (crops), J. R. Shay (vegetable and fruits), and R. H. Painter (insect resistant plants). In addition there is a discussion of antagonism and its implications in plant disease control, by W. C. Snyder; of host nutrition and its reaction to pests, by J. G. Rodriguez; control of screwworm, by E. F. Knipling; and effects of chemical control of diseases and insects on biological balance in orchards, by A. D. Pickett. All these papers sift a broad knowledge of biology and channel this knowledge to specific practical control applications. The most imaginative and successful campaign has been the release of irradiated sterile male screwworms, which mated with normal wild females and caused them to lay infertile eggs. By 1959, this had led to apparent eradication of the population east of the Mississippi River, but there were a few additional occurrences in 1960.

The complex and controversial subject of pest control has been covered objectively in this book, however, a symposium volume seldom, if ever, completely resolves any one problem. Such problems as the side effects of environmental change, or pestresistance to chemicals, are not fully discussed. The information presented can be valuable in making decisions on resource use and deserves the attention of biologists, conservationists, and pest control officials.—*John L. George,* Patuxent Wildlife Research Center, Laurel, Maryland.

Better Grassland Sward—Ecology, Botany, Management, by André Voisin. (Translated from French by Catherine T. M. Herriet) *Crosby Lockwood and Son Ltd., London, or Albert J. Phiebig, Box 325, White Plains, N. Y. 341 pages. 1960. $8.00.*

The author is an imaginative and thoughtful farmer, biochemist, and popular author on agricultural subjects. He is a good observer and carries out experiments on his own land at Dieppe, France. An avid reader, he is in touch with pasture and soils technicians on the continent and in England and New Zealand. His method is to organize available literature and data so as to weave them into support for a number of general principles which he is enthusiastically developing. Out of nearly 300 references upon which he has drawn, about 10 per cent are American and include such names as Albrecht, Blaser, Clements, Huntington, Lunt, Mulder, Neller, Shantz, and Slater.

The translator is the wife of an eminent Scottish pasture investigator, Dr. J. B. D. Herriot, and writes lucid English although a number of technical expressions will surprise American range men and ecologists. Readers can infer meanings from the context, but a glossary in U. S. vernacular might include (reviewer's equivalent in italics): flora=*vegetal composition,* evolution=*succession,* bottom grass=*leaves borne low* (endure grazing well), top grass=*leaves high* (vulnerable), natural selection=*relative palatability,* ley=*temporary pasture,* marl=*lime.* rational grazing=*use timed with the S-curve of grass growth.*

The book consists of 63 "chapters" organized into 16 parts. The plan is to bring in experimental data, often as tables, and then quickly offer interpretations, conclusions, and opinions of the author. The arrangement of these brief chapters (often only 1½ pages) is fairly logical and readable. The distribution of space, however, would astonish many American publishers; actual author's original text, 40 percent; direct quotations, 6 percent; tables (also largely quoted), 16 percent; and headings, sub-heads, footnotes and blank space, 38 percent. The book is sometimes tiresome for continuous reading because of many breaks and interruptions such as numerous footnotes. Latin names of plants are conveniently available and it is fortunate that quantities are usually given both as pounds per acre and kilograms per hectare.

At some point or other in the discussion, almost every imaginable factor that could affect grassland is discussed. Many phases of chemical, physiological, and ecological problems are treated in connection with the artificial *livestock - cultivated plant community.* A favorite approach is to remind the reader that a particular factor will modify the effect of another factor. Double or three - way effects are frequently pointed out. No one could say that M. Voisin treats only isolated direct factors.

Discussion of the "years of depression" (*Hungerjahre*) is interesting. The term refers to decline in stand and yield after an initial period of vigor in reseeded pastures. The reduced yield is attributed to rapid oxidation of soil organic matter and disturbance of soil structure. During recovery of "natural conditions" earthworms increase and assist in improving the soil. Harrowing or discing at this time is considered undesirable.

The last part of the book lays great stress upon the role of earthworms as related to soil structure and essential mineral cycles. Earthworms (and enchytraeids) are said to have vital functions in: improving pH; facilitating assimilation of Mo, N, and other nutrients; and improving grazing qualities of swards. The book builds toward a dramatic ending, asserting that since our "animals under the grass weigh at least twice as much as the cattle or other stock . . ." grazing the land, we should domesticate and improve these minute soil animals. The Pharaohs owed more to worms than to their thousands of slaves because the wormcasts of the Nile Valley were ten times that of the arable soils of Europe. Shakespeare assists in the closing statements ". . . without earthworms men could not create civilizations . . ." — *Paul C. Lemon,* State University College of Education, Albany, New York.

Trees, Shrubs and Woody Vines of the Southwest, by Robert A. Vines. *University of Texas Press, Austin, Texas. 1104 pages. 1960. $25.00.*

While $25.00 may seem a monumental price, Vines has produced a monumental book. If compared with other books on a weight-price ratio alone, this 6½ pound tome would be a bargain. Its content and quality make it even more so. Excellent black and white drawings by Sarah Kahlden Arendale are used to illustrate most of the 1231 species described. Page size is 8½ x 11 inches, the same as the *Journal of Range Management.* A two - column per page format is used throughout. Illustrations, uniformly ¼ - page in size, are inserted directly into the text, usually within the species' write - up. A fine - quality, white, glare-proof paper adds appreciably to the book's value.

To many people, the title may suggest a book of desert trees, shrubs and vines. For this reason, the title could conceivably lose sales for the book, even in Vines' native southeast Texas. The author's admittedly modified definition of the "southwest" includes Arkansas, Louisiana, Texas, Oklahoma and New Mexico. Since this area is the meeting place of southern pines, plains, and desert, the book should prove useful in the deep south as well as in Texas and the desert southwest. Out of 48 trees, shrubs and vines common on pine uplands and sandhills of south Alabama and northwest Florida, 45 are described in the book. The same wide overlap probably can be found on the desert side of Vine's "southwest."

This is not a taxonomic manual but the descriptions and illustrations should provide a valuable cross-reference to southern and southwestern plant keys. Information in the book will be of interest to professional range and wildlife men, foresters, teachers and students of botany or dendrology, and nature - lovers in general. Plant descriptions are grouped according to families, with 102 families represented. Each plant write-up includes, in addition to the scientific and most comon vernacular name, the following sections: FIELD IDENTIFICATION, FLOWERS, FRUIT, LEAVES, TWIGS, RANGE, REMARKS. The REMARKS section contains a wealth of reference information, including a literal translation of the generic and specific names, other common names, livestock or wildlife food value when applicable, thumbnail biographies of persons for whom plants were named, and plant uses. Other headings were added when needed, such as VARITIES, SYNONYMS, BARK, WOOD, MEDICINAL USES, and PROPAGATION. The write - ups suggest that the author read everything he could get his hands on concerning each plant. His bibliography of over 400 publications seems to bear this out.

Vines mainly followed Kelsey & Daytons 1942 *Standardized Plant Names* as a source for common names. Other manuals were consulted, however, and the author admits to coining a few names. Scientific names were gleaned from the most recent monographs and manuals, following the rules and regulations of the 1956 *International Rules of Botanical Nomenclature.* While such a voluminous work is bound to contain typographical and technical errata, spot-checking has so far failed to turn up any. Plant names and author citations, a common source of typographical oversight, show evidence of meticulous proofreading.

In addition to the bibliography, the appendix includes a glossary (with illustrations of flower parts, inflorescence types and leaf characteristics), acknowledgements, and separate indices for scientific and common names. — *Harold Grelen,* Southern Forest Experiment Station, Brewton, Alabama.

CURRENT LITERATURE

Edited by Lee A. Sharp and E. W. Tisdale, College of Forestry, University of Idaho, Moscow, Idaho

RANGE AND PASTURE MANAGEMENT

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WITH THE SECTIONS

UTAH

A $1,500 scholarship for use by a range management student at Utah State University has been awarded by the Rob and Bessie Welder Wildlife Foundation of Sinton, Texas.

James E. Bowns, Jr., Castle Gate, a senior at USU, will be recipient of the award for 1961. Announcement of the award was made by Dr. Clarence Cottam of the Welder Foundation, through Dr. Thaddis W. Box, assistant professor of range management at USU.

Mr. Bowns was selected because of his scholarship and leadership at USU, Dr. Box said. He recently was named "Son of Paul" as the outstanding student in the college of forest, range and wlidlife management.

The scholarship will support study toward a master's degree. Course work will be at USU and research will be on grazing problems on a south Texas ranch.

The Welder Wildlife Foundation is a research and education agency founded by the late Rob Welder to further knowledge of wildlife in relation to rangeland use. The program is implemented by awarding scholarships to outstanding students for graduate work, through sponsorship of publications in the field of resource use, and through research and education activities of the foundation staff, Dr. Box explained.

Gary Oliverson, Preston, Idaho senior, has been chosen as Chairman of the Utah State University Student Chapter of the Utah Section, American Society of Range Management for the coming year. The Student Chapter functions both as a campus club in range management and as an organic part of the parent Utah Section. Members of the student group also fill responsible positions on committees in their professional society. Other newly elected officers include, *Norman Huntsman*, Cedar City, Vice Chairman; *Austin Munson*, Cedar City, Secretary-Treasurer; *Jim Bowns*, Castle Gate, Director; and *Richard Dee*, Amarillo, Texas, Director. *Dr. Thadis W. Box* and *Dr. John F. Vallentine* were selected faculty advisors.

Student Chapter member, *Gerald Nyborg*, was honored at Utah State University by being selected as a finalist in the "Scholar of the Year" contest, sponsored by Sigma Nu Fraternity. The Robins Awards are an annual award of the fraternity to encourage excellence in several fields.

KANSAS-OKLAHOMA

After studying the youth camp activities of other sections, this section has decided to conduct similar ones in each of the two states. The purpose is to give training in the art and science of range management to a few young men and to assist them in bringing improved range management to their local communities.

The Consumers' Cooperative Association has agreed to co-sponsor the participants and share the planning of camp activities. On his return from camp each participant will report his experiences to FFA and 4-H Club groups, Co-op meetings, Service Clubs, etc.

The camp will be held at the Rock Springs 4-H site near Junction City August 30 thru September 1. The students will arrive the afternoon or evening of August 29. There will be a resident supervisor or "range boss" on duty full time in addition to the instructors.

For 1961 the Kansas camp will be limited to representatives from 12 range counties designated by the sponsors. Selections will be from the 1961 and 1962 graduating classes of all high schools in each county.

NEWS AND NOTES

National Grasslands

The name "Crooked River" has been chosen for the Pacific Northwest's only National Grassland. It was selected by Richard E. McArdle, Chief of the Forest Service, for the 106,000-acre area formerly known as the Central Oregon Land Utilization Project. Throughout the nation, 4 million acres of land utilization project lands were redesignated "national grasslands" in June 1960, but unit names were not chosen at that time.

The Crooked River National Grassland, in Jefferson County south of Madras, derives its name from the colorful Crooked River which flows through it. The spectacular Crooked River canyon is one of the prime attractions of the region.

National grasslands in other states will receive such picturesque names as Thunder Basin, Cross Timbers, and Black Kettle. The lands, mostly in the Midwest, were purchased by the Federal Government in the depression years of the 1930's to take them out of cultivation and to develop a program of land conservation based on grassland agriculture. Many require careful management to preserve soil resources. Much of the area has been reseeded to grass. The "dust bowl" years proved they were unsuited for cultivation.

Society Members Honored by USDA

Two members of the American Society of Range Management were among employees of the U. S. Department of Agriculture honored May 23, 1961, in a special ceremony on the Washington Monument grounds at Washington, D. C.

Heading the list of ASRM honorees was Thomas L. Ayers, Assistant to the Administrator of the Agricultural Conservation Program Service, who received one of the six Distinguished Service Awards presented by Secretary of Agriculture Orville L. Freeman.

Ayers was the first chairman of the ASRM committee on international cooperation with organizations of other countries, and has served continuously in that capacity. He is a Fellow of the Soil Conservation Society of America and a member of the American Society of Agronomy.

Tom is perhaps best known for his long service in helping develop and adapt farm conservation programs, his work to insure the administration of these programs through locally elected farmer committees, and his efforts to correlate these programs with the conservation efforts of other Federal, State and private conservation agencies. His citation reads, in part: "For inspiring leadership in developing farmer committee administration of farm programs and engendering cooperation between these committees and many conservation forces, permanently benefiting agriculture, the conservation movement, and the nation."

Prior to joining the Department of Agriculture in 1934, Ayers planned and taught agricultural education programs in South Carolina high schools and at Clemson college where he attained an associate professorship in agricultural education.

Dr. Robert S. Campbell, Chief of the Division of Range and Watershed Management Research at the Southern Forest Experiment Station, New Orleans, has been awarded the U.S. Department of Agriculture's Superior Service Award.

Dr. Campbell's citation was "For developing range utilization standards, improvement of range inventory procedures, skillful coordination of livestock and timber, and for inspirational leadership in multiple use of southern forests."

Since he first joined the Forest Service in 1925, Dr. Campbell has been active in range research throughout the United States. From 1943, when he came to the Southern Station, Campbell has developed many important range inventory procedures. He also has done much to show how cattle raising can be a compatible and profitable use of southern forest lands.

Along with other range scientists, Campbell was responsible for the organization of the American Society of Range Management, which is now international in scope. He served as President of that Society in 1958, and for three years was editor of the Journal of Range Management.

Dr. Campbell has authored over 100 publications on range management in the United States, most of them pertaining to the South and Southwest. Several of his booklets are in use by universities as instructional aids.

In addition to his range and watershed work, Dr. Campbell has, since 1955, organized and developed a program for wildlife habitat research in the South. These investigations promise to provide management guides that will benefit foresters as well as sportsmen, and play an important part in the successful multiple use of southern woodlands.

National Science Foundation

The Division of Biological and Medical Sciences of the National Science Foundation announces that the next closing date for receipt of basic research proposals in the life sciences is September 15, 1961. Proposals received prior to that date will be reviewed at the fall meetings of the Foundation's advisory panels and disposition will be made approximately four months following the closing date. Proposals received after the September 15, 1961 closing date will be reviewed following the spring closing date of January 15, 1962.

Inquiries should be addressed to the Biological and Medical Sciences Division, National Science Foundation, Washington 25, D.C.

Taylor Receives Leopold Medal

Dr. Walter P. Taylor, 72, of Claremont, California, was given the Aldo Leopold Memorial Award Medal in recognition "of distinguished service and outstanding accomplishment to the cause of conservation" at the annual banquet of the North American Wildlife and Natural Resources Conference in Washington, D.C., on March 7.

The highest honor that is bestowed by The Wildlife Society, a continent-wide professional organization of fish and wildlife scientists, the Leopold Medal is given in the memory of the late Aldo Leopold, acknowledged pioneer of modern-day wildlife management.

A lecturer in conservation education at the Claremont Graduation School since 1954, Dr. Taylor also serves with the American Institute of Biological Sciences as a lecturer before high school and college groups. He retired from government more than 10 years ago, after 35 years association with the Bureau of Biological Survey and its successor, the U.S. Fish and Wildlife Service.

Taylor has co-authored two well known books, "The Birds of the State of Washington" and "Deer of North America," and has published more than 300 bulletins, monographs, and papers on ecology, zoology, and natural resources conservation.

SCSA Meeting

Orville L. Freeman, U.S. Secretary of Agriculture, will deliver an address at the 16th annual meeting of the Soil Conservation Society of America. Freeman's presentation will be made on Monday evening, July 31, at Purdue University, site of the Society's 1961 meeting.

'Land Use in a Changing Agriculture' is the theme of the meeting this year, according to Walter C. Gumbel, Society president from Fairmont, West Virginia. The program will challenge all who attend. All who have an interest in American agriculture are invited to come to hear Secretary Freeman speak and everyone is welcome at any portion of the Society's meetings.

Over 1,000 professional conservationists from all areas related to renewable natural resource development are expected to register for the conference which begins July 30 and concludes on August 2. Frank H. Mendell, annual meeting program chairman indicates that 31 presentations will be made by internationally known authorities during the sessions.

The Society will name several individuals to the Fellow Degree and Honorary Member ranks during the meeting. These coveted awards are the highest recognitions given by the organization. Tours of outstanding conservation projects in the Lafayette area will also be a part of the program.

The Soil Conservation Society of America, with offices in Des Moines, Iowa, includes among its membership of over 10,500, individuals from all areas of endeavor in the conservation field. National committees and 110 local chapters carry out the work of the Society. Six new technical study committees have been appointed this year and are now working on problems related to land utilization, conservation education, land zoning, outdoor recreation, mined area restoration, professional conservationist training, urban-suburban conservation problems and water resources management; 84 nations are represented among the general membership of the Society.

Wildlife Program for National Forests

"Operation Outdoors, Part 2," a wildlife habitat management program for the national forests, has been announced by the Department of Agriculture. It is a more detailed presentation of the wildlife phase of the national forest program already approved by Congress and commonly known as Operation Multiple Use.

Operation Outdoors includes planting shrubs, grasses and herbaceous plants on 1.5 million acres of game range; clearing openings, food patches, and game ways for wildlife in dense vegetation on 400,000 acres; and enhancement of 7000 miles of fishing streams and 56,000 acres of lakes by stabilizing banks, planting streamside cover, and constructing channel improvements. The cost is estimated at $25.6 million over a 10 to 15 year period.

TENTATIVE PROGRAM
FIFTEENTH ANNUAL MEETING
AMERICAN SOCIETY OF RANGE MANAGEMENT
HOTEL DRISCOLL—CORPUS CHRISTI, TEXAS
JAN. 23-26, 1962

TUESDAY AFTERNOON, JAN. 23, 1962

Theme: Rangelands of the Southwest and Mexico
Dr. R. A. Darrow, Chairman
Martin Gonzales
(Climate, Soils, Topography and Vegetation of Arizona, New Mexico, Texas and Mexico with emphasis on convention state)

WEDNESDAY MORNING, JAN. 24, 1962

Theme: Rangelands of the Southwest and Mexico (continued)

WEDNESDAY AFTERNOON, JAN. 24, 1962

Field Trip to King Ranch (Under direction of Local Arrangements Committee)

WEDNESDAY EVENING, JAN. 24, 1962

Free—No scheduled activities

THURSDAY MORNING, JAN. 25, 1962

Keynote Session—Range Management—Advancement Through Cooperation
G. W. Thomas, Chairman

THURSDAY AFTERNOON, JAN. 25, 1962

Split Sessions
Section A—Range Production and Economics
Milton Sechrist, Chairman
Section B—Research Methods and Techniques
J. J. Norris, Chairman
Section C—Range Wildlife
Dr. Clarence Cottam, Chairman

THURSDAY NIGHT, JAN. 25, 1962

Social Hour and Banquet (under direction of Local Arrangements Committee).

FRIDAY MORNING, JAN. 26, 1962

General Session: International Cooperation in Grassland Management (Invitational and volunteer papers from countries other than U. S.)
Dr. Thomas L. Ayers, Chairman
George E. Bradley

FRIDAY AFTERNOON, JAN. 26, 1962

Split Sessions
Section D—History of the Range
Tom Copeland, Chairman
Section E—Range Improvement Practices
Paul Howard, Chairman
Section F—Range Condition and Trend
Pete Taylor, Chairman
Joe Fallini

SATURDAY, JAN. 27, 1962

Optional Tours—Corpus Christi and Vicinity, Welder Wildlife Foundation, Monterrey, Mexico, (under direction of Local Arrangements Committee).