Alfalfa for Dryland Grazing
Abstract


Arthur C. Wilton, chairman
Committee on alfalfa for dryland grazing
Central Alfalfa Improvement Conference

This publication is a compilation of literature review and concepts by alfalfa breeders, agronomists, and a range scientist on dryland grazing in the Northern Great Plains and other Western States. The authors report on such aspects of alfalfa production as persistence under dryland grazing, physiological characteristics contributing toward longevity, diseases and insects of alfalfa, and availability of sources of germplasm.

KEYWORDS: alfalfa, dryland grazing, crested wheatgrass, Russian wildrye, legumes, drought

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Preface

Legumes now are being used where, several years ago, their use would have been impractical and uneconomical. Escalating energy demands and high oil and nitrogenous fertilizer prices have caused farmers and ranchers to expand legume acreages. In the plains of the West and in some intermountain areas, this means expanded alfalfa acreages. We now believe that the alfalfa species-complex, without doubt, is the toughest and most productive of the legumes for rangeland and dryland pasture use.

With increased interest in dryland legumes generally, and in alfalfa particularly, we cannot help but realize the research challenges afforded by and the immense benefits to be gained through dryland alfalfa research. For example, of the nearly 100 million acres of grassland in the three northern States of the Great Plains—North Dakota, South Dakota, and Montana—more than 90 percent is grazing land. Alfalfa can increase the productivity of much of this area. With acreages of such immensity, huge yield increases are not necessary to escalate our national livestock production. Yet, in specific instances, beef production on dryland has been doubled by adding alfalfa.

The problem that ranchers and farmers face, however, is continued and reliable production. All growth, productivity, and persistence factors necessary to ensure continuous production of a range alfalfa are not yet known. The various types of alfalfa compatible with different grazing systems or with various rangeland macroenvironments and microenvironments are also unknown.

The problems in alfalfa breeding for rangeland and for dryland pasture may be more diverse than those encountered in breeding for hay production, particularly where hay is produced under conditions of adequate soil moisture. Because grazed alfalfa means livestock use, livestock management must be considered as well as management of the grass-legume mixture. Alfalfa in rangeland is exposed to varied environments, not only from year to year but also from location to location. If alfalfa is to be used in these varied environments, then the specific growth-governing environmental factors must be isolated and their effect on alfalfa growth must be investigated. Finally, the available alfalfa germplasm should be surveyed, and the most successful genotypes should be delineated if additional cultivars of range alfalfa are to be produced and used.

A committee was assembled, therefore, (1) to review the literature concerning the persistence of alfalfa under dryland grazing; (2) to develop and state, insofar as possible, concepts of the salient physiological characteristics contributing toward stand longevity under range conditions; and (3) to suggest germplasm sources that might contribute toward easy establishment and stand longevity under range conditions.

The committee is a diverse group because the problems are diverse. It consists of three alfalfa breeders, two research agronomists, and one range scientist. One research agronomist, throughout his career, has specialized in the physiology of dryland legumes; the other has specialized in grazing management in the Northern Great Plains. All the group are now in the Northern Great Plains Region or were situated there previously. All are vitally interested in dryland alfalfa. This publication is a report of the committee's work.

The approach in this publication has been that each researcher independently review the literature on a particular phase of alfalfa in dryland agriculture. One section is devoted to grazing management, one to range ecology, one to physiology related to persistence, one to pests of alfalfa in rangeland, and one to availability of germplasm. Each section will stand on its own, yet all contribute to the general knowledge that breeders, range management specialists, and range scientists must know if alfalfa is to succeed as a dryland legume.

The authors wish to thank the National Alfalfa Improvement Association for sponsoring the committee.
Alfalfa In Western Grazing Management Systems
Russell J. Lorenz

Introduction
References showing that legumes in a grass sward increase herbage yield and crude protein content and improve forage palatability and digestibility are found easily in both scientific and popular literature. On a worldwide basis, alfalfa is considered the most widely adapted and the most useful legume known. Another fact almost as commonly known is that legumes, particularly alfalfa, improve animal performance whenever they are included in the ruminant diet.

Literally thousands of worker-years have been spent on alfalfa breeding and management research. Volumes have been written on the merits of alfalfa, and its history parallels that of all major civilizations. Small wonder, therefore, that alfalfa has been dubbed "queen of the forages" (7).

But the Queen is not a simple creature. What is so easily referred to as "alfalfa" is, in reality, a complex of species capable of hybridization. Herein lies part of the secret to wide adaptability and high productivity found in alfalfa. In the past, scientists, seed producers, farmers, and all concerned with alfalfa favored the more productive lines—those capable of producing the most forage on productive soils adequately supplied with water. Because of bloat potential, few would risk grazing alfalfa, and certainly no one would try to raise alfalfa in areas of low precipitation unless these areas could be irrigated. Consequently, geneticists and agronomists devoted their lives to selecting plant materials of the upright types suitable for producing hay and to developing management systems suited to the more favorable production situations, while the prostrate and decumbent growth forms with fibrous and creeping roots, suitable for dryland grazing, usually were discarded.

The merits of alfalfa were heard by those of us in range management in the arid and semiarid Great Plains and Western States. Some tried raising and grazing alfalfa in these areas with some degree of success but, more often, with poor or even disastrous results. A few alfalfa breeders did select plant types adapted to the arid and semiarid lands, notably those at Swift Current, Saskatchewan, Canada, and at Brookings, S. Dak. These breeders sacrificed yield in favor of persistence under drought and with limited soil water supply. Getting selections from these lines released as cultivars was difficult, however, because they did not look like improved lines when tested against the conventional hay types.

Time and economic conditions do change, and with them demands and standards also change. Farmers, ranchers, scientists, and those in agribusiness now are engaged in a meager, but gratifying, effort to find a legume suitable for grazing use in semiarid and arid grasslands. At the present time, alfalfa is the legume that holds the greatest promise for success (6, 17). In this report, I will briefly outline the relatively small amount of information published in the last 20 years, related to grazing use of alfalfas in the Great Plains and Western States. This should not be considered an exhaustive review because information on alfalfa often was included in a rather secluded fashion in other grazing research reports.

Literature Review
Throughout the years, dryland alfalfa-grass mixtures have been grazed on a limited basis in the Great Plains of United States and Canada and in the Western United States. Most of the research and most of the farmer-rancher usage, however, have been with alfalfa seeded with crested wheatgrass, Russian wildrye, or intermediate wheatgrass. Recent development of interseeding technology opened new management doors by providing a means of introducing alfalfa and other species to native range and to established stands of seeded grasslands.

Ranchers or farmers who have successfully grazed alfalfa-grass mixtures, or have interseeded legumes into native range, often have their efforts documented in the popular press. In most cases, these ranchers and farmers are pleased with the results and are in favor of developing technology and plant materials to improve the practice. One Montana rancher expressed his enthusiasm for alfalfa by publishing in a technical journal. He includes alfalfa in a system that works for him (12).

Grazing Trials—Research at Dickinson, N. Dak., compared crested wheatgrass pastures with crested wheatgrass-alfalfa pastures (20). Throughout the 7-year trial, the crested wheatgrass-alfalfa pasture was superior to the crested wheatgrass pasture in forage and beef production. Yearling steers used as test animals showed no difference in daily gain per head, although daily forage consumption averaged 17.5 lb dry matter per head per day on the crested wheatgrass and 17.0 lb on crested wheatgrass-alfalfa. The average number of pounds of forage required per pound of gain was 8.4 on the crested wheatgrass and 8.1 on the crested wheatgrass-alfalfa.

Research at the Eastern Colorado Range Station north of Akron (5), at the Archer Substation east of Cheyenne, Wyo. (15), and at the Northern Great Plains Research Center, Mandan, N. Dak. (16), all showed an advantage to alfalfa in the mixture for animal performance as well as for forage production. In the Colorado research, intermediate wheatgrass-alfalfa pasture produced 51 percent more forage, had 67 percent greater carrying capacity, and gave 21 lb greater seasonal gain per head than did intermediate wheatgrass without alfalfa. Air-dry forage required per pound of gain was 8.9 lb, and daily air-dry forage consumption was 15.7 lb per head for the intermediate wheatgrass-alfalfa; for intermediate wheatgrass alone, air-dry forage per pound of gain was 8.5 lb and daily air-dry forage consumption was 13.2 lb per head. The advantage for the alfalfa-grass mixture in the Wyoming work increased as the proportion of alfalfa increased, and the intermediate wheatgrass decreased in the mixture.

1 Research leader and research agronomist, Northern Great Plains Research Center, Agricultural Research Service, U. S. Department of Agriculture, Mandan, N. Dak. 58554.
2 Italic numbers in parentheses refer to References, p. 3.
In the 10-year study at Mandan, yearling steers had average daily gains of 2.66 lb for crested wheatgrass alone, 2.63 lb for crested wheatgrass with 40-N applied annually, 2.53 lb for crested wheatgrass with 80-N applied annually, and 2.82 lb for crested wheatgrass with alfalfa. Carrying capacity was significantly higher for the pastures with the legume than for the crested wheatgrass alone but significantly less than for those receiving 40-N or 80-N annually.

A grazing study at Miles City, Mont., compared crested wheatgrass-alfalfa and Russian wildrye-alfalfa with native range, but no direct comparison was made with the grass species without alfalfa (9). For all parameters evaluated, the seeded pastures exceeded the native range when grazed with Hereford breeding cows and calves for 5 years. No management problems were attributed to alfalfa in the mixture, but the authors did question the effect of fall grazing of regrowth on date of beginning grazing the following spring or on the amount of forage produced the following year.

Crested wheatgrass and crested wheatgrass-alfalfa pastures were compared as part of an 8-year study at the Archer Field Station in Wyoming (2). The 8-year average sheep-days per acre was 121, and the lamb gain per acre was 64 lb for the crested wheatgrass alone. For crested wheatgrass with alfalfa, the 8-year average sheep-days per acres was 164, and the lamb gain per acre was 96 lb. The actual daily gains were not reported, but the authors made the following statement: "Analysis of the daily gains made by the animals on these different pastures showed little difference in gains for any given period and for animals of similar age. Exceptions were found on the blue grama-buffalograss pasture, where gains were quite low, and on the grass-legume mixture, where gains were above average."

Mixtures of crested wheatgrass, intermediate wheatgrass, and Russian wildrye, with and without alfalfa, were evaluated as spring pasture using sheep (4) at Swift Current, Saskatchewan. The mixture containing alfalfa exceeded the mixture without alfalfa for all production parameters evaluated. Six-year averages for each parameter with alfalfa were 1,020 lb dry matter per acre; 13.4 lb gain per ewe; 35.3 lb gain per acre; and 333 ewe days grazing per acre. Without alfalfa, 6-year averages for each parameter were 750 lb dry matter per acre; 6.0 lb gain per ewe; 11.0 lb gain per acre; and 257 ewe days grazing per acre.

Bloat is always of concern where alfalfa is included in a pasture; however, finding reports of research designed to evaluate the bloat problem or to document management systems designed to reduce the bloat hazard satisfactorily is difficult. A study at Swift Current (1) involved grazing pure stands of four alfalfa varieties: 'Rambler', 'Siberian', 'Grimm', and 'Alfa'. Steers grazed these pastures for 2 years with a very low incidence of bloat. Although slight bloating sometimes occurred, no animal reached the severe stages. Holstein cows grazed these pastures for 1 year, and virtually no bloat was observed. In all 3 years, 'Rambler' was superior to 'Grimm' and 'Alfa' in yield and carrying capacity. The authors concluded that alfalfa can be used successfully for dryland pasture and that certain varieties are better than others for this purpose.

**Interseeding**—Interseeding has been studied at a number of locations in the Great Plains and Western States (9, 14, 18, 19). Enough successful interseeding has been made to indicate that technology can be developed for introducing alfalfa into existing grasslands; however, research involving grazing of interseeded grasslands is limited.

An interseeded pasture-grazing trial underway at Dickinson, N. Dak. (13), has been grazed with cow-calf pairs for 2 years. Below-normal precipitation has kept production from all treatments low, but the native range interseeded with 'Travois' alfalfa averaged 32 lb more beef per acre than the next highest treatment and 67 lb more than the untreated native range. These results are preliminary but of interest because very little native range interseeded with alfalfa has been experimentally grazed.

**Persistence**—Questions of persistence and longevity are often raised in discussions of introducing alfalfa into grasslands. Many very old stands of alfalfa can be found in the Northern Great Plains of the United States and Canada, and I am sure there are others in the Western States. Some have been documented (11, 17), and I am aware of several very old stands in the Dakotas and Montana that have been grazed for many years. A germplasm collection has been made from many of these old stands, and plans are underway to collect from others.

Campbell (3) conducted a study near Swift Current in which six grass-alfalfa mixtures were grazed with sheep for 4 years, with season of use as a variable. Since no treatment without alfalfa was included, the direct benefit of alfalfa cannot be identified but its persistence is noteworthy. Campbell's study was conducted in a low-precipitation area, during 4 years of below-normal precipitation. The creeping-rooted strain of alfalfa used was described as being similar to 'Rambler'. It maintained its stand in the spring-grazed pastures and persisted strongly in the autumn-grazed pastures but decreased on the continuously grazed and summer-grazed pastures. Campbell concluded that this type of alfalfa would persist and provide excellent pasture when grown with dryland grass species suited to the low-precipitation areas of the Northern Great Plains of the United States.

To summarize alfalfa production in Canada, Heinrichs (8) made a few comments related to use and management of dryland alfalfa related to persistence. I include them here to remind us that grazing management systems need to take into account the increased complexity of adding a species to the system, particularly if an alfalfa is developed for introduction in native range or for use in permanent type seeded grasslands, and if it is expected to become a permanent part of the species complex. The following are quotations from Heinrichs (8):

> "The main principle to follow in the utilization of alfalfa is to avoid frequent cutting or overgrazing.

> "Alfalfa withstands continuous grazing quite well, but it thins out rapidly when closely grazed. Varieties with wide crowns and creeping roots survive better under grazing than tap-rooted types with narrow crowns, provided they are adapted to a region."
—"Do not cut or graze alfalfa during a 6-week period from September 1 to October 15. At this time, carbohydrate reserves are being stored in the roots in preparation for the long dormancy period, and if top growth is removed reserves will be insufficient and plants will suffer from winter killing."

Concluding Remarks
Introducing alfalfa to arid and semiarid grasslands is a viable means of increasing animal output from a shrinking grazing acreage with a minimum of fossil fuel energy input. We cannot expect alfalfa to miraculously improve all grasslands, but we can learn where to use it and when to use it so we can add it to the collection of alternatives available to the range and livestock managers.

To do this successfully, legume breeders need to know what situations alfalfa will be put into in grazing management systems. This will provide the guidelines for selecting materials capable of performing satisfactorily. In all probability, no one cultivar will be best for all situations. Managers need to know the limitations of available cultivars so they can manage for optimum animal product while maintaining the legume-grassland complex on a long-time basis. With these factors as a common ground, a team effort to provide the materials and the technology needed of geneticists, physiologists, pathologists, entomologists, agronomists, animal product while maintaining the legume-grassland complex cultivar of performing satisfactorily. In all probability, no one will be best for all situations. Managers need to know the limitations of available cultivars so they can manage for optimum animal product while maintaining the legume-grassland complex on a long-time basis. With these factors as a common ground, a team effort to provide the materials and the technology needed to make the system work and to make it available to the livestock manager of the arid and semiarid regions of the Western United States and Canada.

References
Environmental Factors And Alfalfa Persistence In Dryland Pastures And Rangeland

Ronald E. Rits

Introduction
The use of legumes in dryland pasture and range is considered beneficial because of increased total forage production, improved animal performance from the presence of the legume, increased use of all forage, and the possibility of increased nitrogen for associated vegetation through the nitrogen-fixing ability of legumes.

Opinions about these proposed benefits from legumes in pasture and rangeland differ widely among scientists working on them. Existing evidence, however, indicates the need for further study to better understand the legume-grass association in dryland pasture and rangeland.

Heinrichs (13) proposes that alfalfa, because of its wide climatic adaptability, is the most promising legume for rangeland use in the temperate regions of the world. Hanson et al. (11) briefly discuss the distribution and adaptation of alfalfa. They reported that alfalfa is distributed worldwide and is well adapted to widely divergent climatic and soil conditions. Yellow-flowered alfalfa (Medicago falcata) has survived at temperatures as low as -62°C (-80°F) and as high as 34°C (110°F). Because of this wide distribution and diversity, improving alfalfa by selection and breeding has been very successful.

Environmental Factors And Dryland Pasture And Rangeland Alfalfas
Much research on alfalfa has been done since it was introduced into the United States.

One report comprehensively reviewed and consolidated alfalfa research results (10). Much of this research was concentrated on the agronomic use of alfalfa for hay and pasture in humid, semiarid, and arid climates, and on irrigated alfalfa in arid climates. Rangeland alfalfa has been studied less. Under dryland conditions, alfalfa has been used for hay production, in seeded dryland pastures in association with grasses, and in a few rangeland seedings. This section discusses the relationship of environmental factors found under dryland pasture and rangeland conditions to alfalfa survival and growth.

Wilsie (31) discusses crop adaptations and distribution and the relationship between crop plants and their environment. He groups environmental factors into three general categories: climatic, edaphic, and biotic. Understanding the relationship of these factors and alfalfas used in dryland pastures or rangeland communities is essential for the success of such systems.

Dryland pastures differ somewhat from rangelands because they usually are established on marginal cropland of reasonable topography and under marginal climate for dryland farming.

Associated species may include one to three grass species, and the pasture will receive moderate to high levels of management. Rangeland, on the other hand, is usually poorer land than dryland pastures and has more rough topography and drier climatic conditions. Associated species usually are more diverse than dryland pastures, and the range areas usually receive less management than dryland pastures. The environmental conditions confronted by alfalfa under these two uses are similar but perhaps more severe in rangeland.

Climatic Factors—Temperature, water supply, and light are the three most important climatic factors related to plant response. All elements of climate are interrelated (14). Vegetative response is affected by all environmental elements interacting to determine plant establishment, survival, growth, and productivity.

Alfalfa used for dryland pasture or rangeland would be exposed to variable climatic conditions. In the areas where dryland alfalfa can be used, seasonal temperatures range from as high as 49°C (120°F) to as low as -46°C (-50°F). Diurnal temperature fluctuations of 40° are common. Annual precipitation may vary from 20 in (50 cm) to below 10 in (25 cm) with periods of drought common at any time. Evapotranspiration rates are high. Day length and, to a lesser extent, light intensities can also vary. Aamodt (1) summarizes well the effect of climate on alfalfa. The most important fact is that alfalfa strains and varieties differ in their climatic requirements.

These climatic conditions often are tempered by associated conditions. The effectiveness of precipitation in localized areas can be influenced greatly by its intensity, type (rain or snow), duration, and annual and seasonal distribution. Temperatures are modified by topographic position and aspect (north, south, east, west). The severity of winter temperatures can be lessened by the insulating effect of snow cover. Light intensities can be modified by topographic position, aspect, and associated vegetation.

Literature concerning environmental physiology of alfalfa was reviewed (5). This review reflects the considerable amount of work done on the germination and growth of current varieties of alfalfa in relation to specific environmental conditions. In another report the response of alfalfa to cold, drought, and heat was reported (15). In both discussions, varieties responded significantly differently to various environmental conditions. The difference emphasizes the need to match varieties with environments where they perform best. Genetic differences also allow for selecting and breeding new varieties for specific environmental conditions.

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2 Italic numbers in parentheses refer to Literature Cited, p. 7.
Edaphic Factors—Edaphic conditions will be a very important environmental consideration for dryland alfalfa. In the semiarid and arid regions, soil properties that affect water infiltration and storage will be of paramount importance to survival and growth of alfalfa. Soil texture, sodium content, slope steepness, and vegetative cover are very important in determining the amount of water infiltration that can take place on a site. Soil texture, soil depth, and salinity levels greatly influence the availability of soil water for plant growth. Soil properties are more important to alfalfa survival and growth under dryland conditions than under higher rainfall or irrigation because the amount of available water for growth is influenced primarily by soil characteristics and is only slightly controllable by management.

Soils vary greatly across the area where alfalfa may be used in dryland pastures or rangelands. The properties of these soils have been documented through soil surveys for much of the area.

Some research has been done on soil water uptake and the importance of subsoil moisture to alfalfa. Kohl and Kolar (19) found that Medicago sativa roots preferentially take up water from areas of high water potential over areas of lower water potential, but water uptake continues in areas of low water potential (even below 1.5 bars). The depth of the roots does not appear to affect water uptake. Kiesselbach et al. (16) found that alfalfa yield decreased as subsoil water was depleted by an alfalfa stand in Nebraska. Irrigating part of the stand replenished subsoil water and improved yield. Both these findings need to be considered when alfalfa is used in either dryland pasture or rangeland.

Redmann (24) found alfalfa varieties were inhibited from germinating by the osmotic and specific ion effects of various salts. Again, certain varieties tolerated the osmotic and ionic effects better. Such osmotic and ionic conditions can be experienced under certain field conditions when establishing alfalfa for dryland pasture or range.

The nutrient levels found in the soil where alfalfa can be used also may be important. Nutritional requirements of alfalfa have been discussed by Rhykerd and Overdahl (25). A comprehensive review of fertilizer experiments with alfalfa from 1915 to 1960 at the University of Connecticut was made by Brown (4) and provides an excellent review of nutrient requirements of alfalfa. The articles provide basic nutritional requirements that must be considered for alfalfa. Under dryland conditions in semiarid and arid areas, however, nutrients may be less important because of the limiting nature of water in most years.

Biotic Factors—To date, the relationship of alfalfa to biotic conditions has been approached mainly from an agronomic standpoint where considerable management was used. In dryland pasture, and especially range situations, biotic factors will be subject to considerably less management control. Dryland alfalfas will have to withstand insects, rodents, grazing, and occasional fire. App and Manglitz (2) discuss insects and related pests in relationship to alfalfa survival and growth. Under dryland conditions, diseases should be a lesser problem than under more humid conditions. The primary insect pest is grasshoppers. Rodents that feed on the roots of alfalfa in a pasture and range area could pose a substantial problem to alfalfa survival.

Competition from associated plants in pasture or rangeland will be important and more severe than under agronomic monoculture situations. Water available for plant growth is fixed, and competition for its use will be intense. Alfalfa competes vigorously for growth factors above and below ground (7). Kilcher and Heinrichs (17) found alfalfa to be persistent in a mixture of grasses in a semiarid region. Both these studies indicate that alfalfa can be a valuable species in dryland pasture and rangeland.

For alfalfa to become part of pasture or rangeland, and to maintain itself, it must be established and continue to reestablish itself because periodical reseeding is not practical. The ability of an alfalfa to revegetate from roots or stems would be a considerable advantage. The effect that competition from other plants will have on seed production and establishment, as well as on vegetative reproduction, is largely unknown but will be crucial to the success of dryland pasture or range alfalfa.

Peters and Peters (23) discuss weeds and weed control for alfalfa. Alfalfa, in general, was found to be susceptible to weed competition in the seedling stage. Another study reviews literature on competition between establishing forage species with reference to alfalfa (3). Tesar and Jackobs (28) discuss requirements and methods of alfalfa establishment. White (30) presents information on establishing lucerne (M. sativa) in uncultivated land in New Zealand. Establishing dryland alfalfa under semiarid and arid conditions has been a problem, although good success under favorable precipitation patterns and amounts has been reported.

The ability of alfalfa to fix nitrogen is important in that it should supply itself added nitrogen under dryland pasture and rangeland conditions where nitrogen is often limited. Burton (6) discussed the basics of nodulation and symbiotic nitrogen fixation by alfalfa. The question of whether extra nitrogen will be available for associated vegetation is of interest but quite controversial. Simpson (26) reported lucerne released nitrogen gradually during an experiment studying the transfer of nitrogen from pasture legumes to an associated grass under several systems of management in pot cultures. Wilson and Wyss (32) discuss this question comprehensively. They point out that under most conditions where extra nitrogen was found, growth conditions were excellent. Under dryland pasture and range conditions, where soil water is often limited, the amount of excess nitrogen for associated plants may be small. Yet the possibility of available excess nitrogen exists and needs better understanding and documentation.
Rangeland alfalfa has to survive and grow under the limited management it will receive. Conventional management and use of alfalfa are discussed by Graumann and Hanson (9) and Van Keuren and Marten (29). Because alfalfa is a desirable forage species, it is selectively grazed by livestock and wildlife. Even under proper stocking rates, the grazing pressure it receives could be quite heavy. A range alfalfa also must be able to survive chemicals and fires used for occasional weed and shrub control in rangelands. An important characteristic of an alfalfa that would best survive heavy grazing and fire would be one with vegetative primordia close to or below the ground. Smith (27) discusses this characteristic for several alfalfa varieties. Because livestock are under less observation and control, rangeland alfalfa should have a low bloat tendency.

Promising Alfalfas For Dryland Pastures And Rangelands

Heinrichs (13) presents the most probable reasons for the noninclusion of legumes in current range improvement programs as poor survival of legumes under heavy grazing and the wariness of ranchers and farmers about bloat hazard. Lowe et al. (20) discuss in detail the current alfalfa varieties that are adapted to dryland production. Varieties considered as pasture type alfalfa include 'Nomad', 'Rambler', 'Rhizoma', 'Sevelra', 'Teton', and 'Travois'. They further point out that varieties used for pasture have low-set crowns, a procumbent growth habit, drought tolerance, marked fall dormancy, slow recovery from cutting, and a high degree of winterhardiness. These varieties usually produce less forage yield than varieties used for hay. Two papers by Graumann (8) and Heinrichs (12) discuss varieties of alfalfa in more detail concerning their suitability for dryland pasture and rangeland use.

Several varieties of alfalfa, therefore, are now available that could be a beneficial component of dryland pastures and rangelands. The benefits from alfalfa in pasture or rangeland areas need to be better documented and clarified, and better understanding and techniques are needed to establish these varieties. Research is needed on the beneficial minimum management of alfalfa in dryland and range communities along with better documentation of these varieties in relation to bloat incidence.

A review of older papers concerning alfalfa is of great interest from a range ecology standpoint (18, 21, 22). Many of the characteristics described for these early alfalfas are important for the persistence and success of many dominant range plants found today in dryland pastures and rangelands. The ability of selection and breeding programs using these early alfalfa plants to develop better dryland alfalfas, particularly for range use, appears to be excellent.

If the need and benefit of rangeland alfalfa warrants, an added collection of *Medicago falcata* could be made from its original populations. This new collection could serve as a new breeding population to improve alfalfa for use in dryland forage communities.

Summary

From this discussion, the environmental factors limiting alfalfa growth and survival can be summarized as follows. Climate of the semiarid and arid areas where alfalfas would benefit pasture and rangeland involves limited precipitation amounts, often occurring irregularly. Periods of drought are common, and water is the most important single environmental factor. Temperature exhibits wide seasonal and diurnal fluctuations, and evapotranspiration rates are high. Winterhardiness is required over a large portion of the dryland pasture and rangeland area. Light intensity is fairly constant throughout the area, with daylength and its effect on flowering and seed set being more variable.

Soils are most important in how they affect available soil water. Nutrient availability should be of secondary importance because soil water is inherently limiting. Pasture and rangeland alfalfa is subject to such pests as grasshoppers and rodents. Heavy grazing pressure from both livestock and wildlife can be expected. Alfalfa must survive the occasional management use of fire and chemicals for weed and shrub control. Because of limited control over range livestock, alfalfa used in rangeland should provide a low incidence of bloat.

Competition for nutrients and water for establishment, growth, and survival will be intense and largely outside the control of management. The ability of alfalfa to fix and supply itself with nitrogen may give it a competitive advantage in areas where nitrogen is limited. The ability of dryland pasture and rangeland alfalfa to go dormant during periods of unfavorable moisture and temperature, like other persistent dryland plants, would be beneficial.

An alfalfa that best meets these environmental requirements will be most successful in dryland pastures and rangelands. Production can be lower, but persistence and sustained yield under these conditions will determine its value as a component of dryland forage communities.
Literature Cited


Selection For Drought Resistance In Alfalfa

Clee S. Cooper, John R. Carlson, and Raymond L. Ditterline

Introduction

Little information is available on drought resistance in alfalfa (Medicago sativa L.) (25). Drought reduces yield, quality, plant height, and vigor (40). The development of adapted dryland alfalfa varieties would enable limited water resources to be used more efficiently.

Developing rapid screening and selection techniques would enable plant scientists to measure many plants for traits linked to drought resistance and to determine, eventually, which cultivars are best suited for dryland environments. In searching for criteria that may permit rapid selection for drought resistance, the way drought affects plants and the morphological and physiological characteristics associated with drought becomes important.

Influence Of Drought On Plant Growth

Drought is a "sustained period of significantly subnormal water or soil moisture supply" (57). Low rainfall is the basic cause of drought, but other meteorological factors, such as wind, air temperature, or radiation, also contribute to water deficit (50).

Nearly all physiological processes within a plant are affected by water deficit. One study shows that water serves four general functions in plants: (a) It is a major constituent of physiologically active tissue; (b) it is a reagent in photosynthesis and hydrolytic processes such as starch digestion; (c) it is the solvent in which sugars, salts, and other solutes move in the plant; and (d) it is important in maintaining turgor for cell enlargement and growth (30).

Wright (60) states, "there is little question that aridity seriously limits germination and initial growth of plants." Moisture stress may reduce the rate of germination and seedling growth (27) or alter the metabolism of imbibing and germinating seeds to the point where internal processes delay or even halt germination (56).

Most plants show retarded or stunted growth with water stress (32). Pulgar and Laude (42) observed a reduction in the number and length of shoots in alfalfa regrowth after stress, that persisted up to 6 weeks following stress, with no evidence of tissue mortality. Perry and Larson (40) found a reduction in the number of stems per plant, the internodes per stem, and the internode length of the primary stem following water deficits in alfalfa.

A series of metabolic changes and metabolic and mechanical injuries occurs in dehydrated tissues. Dehydration of the protoplasm (30) reduced photosynthetic capacity. Stomatal closure and related reduction in photosynthesis during drought result in reduced leaf area and activity (32). Respiration rates may exceed those of photosynthesis during water stress (32). Structural changes in the protoplasm resulting from cell water loss may cause mechanical injury (45). Drought retards differentiation of cells and tissues and hastens their maturation, which causes decreased development of stems, leaves, and fruits (29). It also reduces rates of translocation and nutrient uptake and inhibits synthesis of cytokinins and gibberellins in the roots (32). Cell division may be influenced less by drought stress than is cell elongation (20). Increased wall thickness and decreased succulence also result from drought.

Maximum crop yields are dependent on the uninterrupted maintenance of moisture supplies throughout the season (50). Plant water balance is affected by a complex combination of atmospheric, plant, and soil conditions (19, 25).

Resistance To Drought And Its Measurement

General Forms of Drought Resistance—Drought resistance mechanisms in alfalfa are unclear as yet (25). A number of factors affecting winterhardiness have been studied, however, and many believe a close relationship exists between mechanisms affecting cold and drought tolerance. One study states that (a) plants hardened to cold also become hardened to drought; (b) drought and cold tolerance both are associated with small cell size; (c) species, and sometimes varieties within species, have parallel rankings for drought and cold tolerance; (d) changes in both drought and cold tolerance are associated with changes in growth; and (e) many of the physiological changes that occur during hardening to drought and cold are similar (34).

Another definition of drought resistance includes "the overall suitability of plants for cultivation under dry conditions" (45). There are two general categories of drought resistance in crop plants (51). Drought avoidance refers to the ability of the plant to evade drought injury. For example, sorghum (Sorghum bicolor L.) (55) and 'Ladak 65' alfalfa remain quiescent during periods of drought. Drought tolerance (51), or hardiness (45), refers to the ability of a plant to survive varying degrees of tissue desiccation. Both of these mechanisms may be present in a plant (51).

Morphological and Anatomical Drought Resistance Factors—Morphological characteristics that reduce water loss help plants avoid dessication. Awareness of characteristics related to drought resistance may aid in selecting drought-resistant alfalfas. Pubescence slows air movement and reduces transpiration. In the soybean (Glycine max Merr.), pubescent leaves reduced transpiration 10 to 20 percent under artificial conditions (59). One report suggested that pubescence could be incorporated to a greater extent in soybean cultivars to improve drought resistance (21). Pubescence, however, is not a common characteristic of alfalfa and is not likely to become a major selection trait for drought resistance.
Plants with thick cuticles (39) and decreased leaf area (43, 54, 55) have been considered drought resistant. Succulent leaves avoid desiccation by maintaining a high moisture content during drought (33, 39).

Growth habit and root proliferation have been related to drought resistance (36, 38, 49, 54). Koch et al. (28) suggest that slow regrowth after first cuttings may be a factor conditioning drought avoidance. They observed that sainfoin (Onobrychis viciifolia Scop.) plants were dormant during long periods of drought stress but that roots continued to absorb water to a depth of 64 in (180 cm). Similar results have been obtained with alfalfa (13). In dry areas, large and highly developed root systems aid plant survival (33, 38, 55).

Many studies reported the effect of stomata on plant drought resistance (2, 9, 15, 33, 37, 55). Teare et al. (55) reported that sorghum's "ability to swiftly close its stomata" was a factor in drought resistance. Dobrenz et al. (15) concluded that drought-resistant clones of blue panicgrass (Panicum antidotale Retz.) had fewer stomata per unit area than drought-susceptible clones. Muenscher (37) found no constant relationship between transpiration rate and stomate density or size. He concluded that the differential water loss observed among species is governed by a complex of factors and not just the size and number of stomata.

Anatomical characteristics in plants also have been studied (6, 8, 45, 53) to determine their role in conditioning plant drought tolerance. Bula (8) states that low alfalfa yields during hot, dry summer periods may be explained by less leaf tissue, decreased leaf area; and smaller, more densely packed, leaf cells. Large cells in the vascular tissue allow for better translocation of photosynthates and water, and large intercellular spaces enhance carbon dioxide diffusion of alfalfa plants grown in growth chambers. Blum (6) reports that genotypic differences in sorghum to dehydration might be caused by differences in cell wall elasticity. Drought-hardy plants also have been purported (33, 45) to have smaller cells. Smaller cells, when desiccated, undergo a smaller proportionate reduction in volume (45).

Physiological Drought Resistance Factors and Selection Techniques—The literature on the effect of water deficits on plant physiological processes is extensive and will not be discussed in detail here. For a list of references on this subject, see Laude (32).

Selecting for drought resistance has met with limited success. A number of techniques, most related to plant physiological processes, have been tried, and these will be presented in this section.

Germination Against Stress—Several workers have attempted to relate germination in sodium chloride, mannitol, and similar solutes to drought or cold hardiness. Rodger et al. (44) found a significant negative relationship between the ability of seeds from alfalfa cultivars to germinate against an osmotic stress and winterhardiness of mature plants. Dotzenko and Dean (17) reported similar results. Larsen and Smith (31) and Heinrichs (24) concluded that germinating alfalfa in sugar or salt solutions is not a reliable method for differentiating alfalfa varieties into winter hardiness classes. Younis et al. (63) found no correlation between seed germination at low potentials and drought tolerance in mature alfalfa plants.

Cooper (12) evaluated winterhardiness of crested wheatgrass (Agropyron desertorum) previously selected for differential ability to germinate in mannitol. Crested wheatgrass clones differed in winterhardiness, but differences were not related to germination against osmotic stress. Sharma (46) found that five forage species differed in ability to germinate in sodium chloride, mannitol, and polyethylene glycol, but tolerance to germination in these solutions was not necessarily an acceptable index of drought tolerance in mature plants. From the studies cited above, we feel that germination against stress holds little promise as a rapid technique for selecting drought-resistant alfalfa lines.

Leaf Water Potential—Relative turgidity (RT) of leaves, RT = \frac{\text{Fresh wt} - \text{dry wt}}{\text{Turgid wt} - \text{dry wt}} \times 100, is a simple and inexpensive laboratory method that should be considered as a technique for measuring drought resistance. Measuring leaf-water potential is more complex, requires more expensive equipment, and is time consuming. Sullivan (51) discusses a number of water potential measurements as follows:

1. Vapor equilibrium. This method is equivalent to diffusion pressure deficit (DPD) and suction tension and requires inexpensive and simple equipment. The basis of the method is to allow several preweighed leaf disc or tissue sections to come to vapor pressure equilibrium with a series of solutions with known water potentials in laboratory jars. This method has limited application in plant breeding because only a small number of samples can be handled.

2. Liquid exchange. This method involves changes in volume or length of tissue strips after immersion in solutions of known osmotic pressure. It has not been particularly useful.

3. Vapor pressure. This technique measures vapor pressure of water in the air of a chamber in which a tissue sample is sealed and which is in equilibrium with the sample. This is a popular technique and usually is measured with a thermocouple psychrometer. An advantage is that the osmotic potentials of plant tissue, soils, and solutions can be measured. A disadvantage is that it is relatively expensive and requires considerable time and skill in setting up apparatus.

4. Beta gage. This technique measures leaf density when a Beta radiation source is placed on one side of a leaf and a Beta detector is placed on the other side. Beta gage measurements have been related closely to RT and DPD in some studies but not in others. It is likely to be too time consuming and inaccurate for determinations with large numbers of samples.

5. Osmotic potential of cell sap. Freezing point depression of expressed sap is the most popular method of determining osmotic potential. The method is limited for selection in breeding because of the time required in making determinations.
Stomatal Measurements—Leaf porometers, which measure internal resistance to gas flow, are used to measure stomatal closure and leaf diffusion resistance. Leaf porometer measurements are reasonably rapid and may be used to monitor diurnal changes in stomatal behavior that may be related to drought resistance. Stomata impressions are taken with silicone rubber or acrylic resins sprayed on leaves.

Stomata length and density have been evaluated in five alfalfa cultivars and in two experimental lines differing widely in winterhardiness (10). Although winterhardy types had higher stomata densities than the nonhardy types, additional work is needed along these lines to study the relation of stomata density to drought resistance of alfalfa.

Measuring Desiccation Tolerance—Desiccation injury from heat, cold, or drought is measured most often by vital staining of tissue (52) or by measuring electrical conductivity of electrolytes exosmosed from leaf disc (14). For screening purposes, desiccation tolerance is difficult to control and tests are time consuming (53). Because desiccation tolerance often is correlated with cold or heat tolerance (34), it is often easier to impose the latter stresses. Sullivan et al. (52) reported that heat tests with leaf discs were good indicators of both heat and drought tolerance. Cooper (11) stressed orchardgrass (Dactylis glomerata L.) seedlings by emersing tops of plants in water at 50°C (122°F) for 60 s. Photosynthetic rate was reduced 70 percent for 1 to 5 h following treatment but recovered to nearly normal 1 week later. Heat tolerance of plants increased with age to 31 days of age and then plateaued. Laude (32) heat stressed two red brome (Bromus rubens L.) ecotypes in air at 54°C (129°F) for 4 ½ h, and then grew them to maturity. Height, number of leaves, and tillers of both ecotypes were depressed significantly, but one was more depressed than the other. Wright et al. (61, 62) used a programed artificial heat environment to evaluate large numbers of seedlings and precisely select superior genotypes within a species for drought tolerance.

Ethylene Determination—Increased ethylene content in drought-stressed plants appears to affect leaf abscission. Ethylene production in petioles of intact cotton plants increased within hours when water deficits developed (35). Water stress also resulted in increased ethylene production in orange (Citrus sinensis Osbeck) leaves (4) and broad bean (Vicia faba L.) (5). Because ethylene content increases with drought stress, drought-resistant lines of a species may be delineated by measuring ethylene following stress. Ethylene is measured readily by gas chromatography, and techniques for its extraction from plants can be simplified. The physiological roles of ethylene in plants and measurement techniques are discussed in an excellent review by Pratt and Goeschl (41). The most common techniques are some variation of placing stressed material in sealed glass containers and withdrawing samples after a period of time (23, 35) or by extracting ethylene from plant tissue under vacuum (5).

Proline Accumulation—Free proline accumulates in leaves of many plants following water stress. This proline accumulation represents a major pathway of N metabolism. Hanson et al. (23) cite many papers that show the main source of free proline accumulated during drought stress is synthesis of proline from carbohydrate via α-ketoglutarate and glutamate. Several research groups have studied genetically controlled accumulation of proline in field crops. In rice (Oryza sativa L.) (3) and sorghum (7), field drought ratings and proline accumulation were not positively correlated. Singh et al. (47) found that proline accumulating ability of 10 lines of barley was positively correlated with their grain yield stability. More recently Hanson et al. (23) in a detailed study with a drought-resistant and a drought-susceptible barley cultivar concluded that proline accumulation followed water stress and that differences in proline accumulation could be accounted for by differences in internal water status. In their studies, the drought-susceptible cultivar accumulated proline faster than the resistant cultivar. They further conclude that selection for high-proline accumulation would likely result in genetic advance toward susceptibility to water stress rather than drought resistance. Using proline as a selection tool appears to be questionable and its determination is probably too time consuming to be of practical value in a breeding program.

Chlorophyll Stability Index—In 1958, Kaloyereas (26) proposed the chlorophyll stability index as a technique for evaluating drought resistance. This index is the difference in chlorophyll light absorption readings from heated and unheated leaves. He found that the critical temperature was 55° to 56° C (131° to 133° F) for loblolly pine (Pinus taeda L.) seedlings. Above this temperature, chlorophyll degradation proceeded rapidly. Significant correlation was found between chlorophyll stability and drought resistance of pine. The method, however, has found use, possibly because of the time required extracting chlorophyll and determining the light absorption. With the advent of such equipment as the portable reflectance meter for estimating chlorophyll concentrations of leaves (58), the chlorophyll stability index technique may warrant further consideration as a screening tool.

Determining Criteria For Selecting Drought Resistant Alfalfas A major problem in breeding for dryland alfalfa is defining the objective. Do we want drought tolerance, avoidance, or both? Do we want plants that can persist on range under stress but are low yielding, or do we select for higher yield and possibly a shorter lifespan?

Survival and drought tolerance are important during the seedling stage. During establishment, any factor that increases rate of germination, root elongation, and seedling vigor also increases chances of seedling survival under dryland or rangeland conditions. In areas where surface soils dry quickly following a rain, seeds must germinate and roots must grow quickly into moist soil layers. Thus, speed of germination and rate of root elongation are drought-avoidance mechanisms. Factors have been reported by workers as components of vigor for a number of species (61). One researcher discusses those relevant to the growth of the legume seedling. Speed of germination and root elongation have been shown to be related to first season growth of birdsfoot trefoil (Lotus corniculatus L.) (17).
The value of rates of seed germination and root elongation in alfalfa need further clarification. Rate of root elongation is more rapid for M. falcata than for M. sativa in the seedling stage (48). This may explain the greater hardiness of the wild alfalfas. Selection for branched or fibrous root-type alfalfa seedlings appears to be heritable (Carlson, John R., Ph.D. thesis, Montana State University, 1981).

On rangeland, alfalfa seedlings may become subjected to drought stress for short or long periods. Selection for drought tolerance (growth during stress) and the ability to withstand tissue dehydration would be important to survival. Screening tests are needed to differentiate drought-tolerant from nontolerant seedlings. One of the easiest and quickest ways may be the ability of the seedlings to form new leaf tissue under applied artificial drought or to resume growth following stress.

Once alfalfa becomes established, both tolerance and avoidance mechanisms become important. While selection of early maturing cereals has increased water use efficiency and yield in the Great Plains, this may not be true for alfalfa. Alfalfa grows best at warm temperatures. A later maturing variety may be more productive than an earlier one in that optimum leaf area index is more likely to coincide with the period of maximum incident solar radiation in June when soil water is still available.

In most of the West, little regrowth is made after alfalfa matures in late June and early July because soils are often at or near wilting point in both July and August. Thus, selecting alfalfa with 'Ladak' type growth (rapid early season growth; slow late-season growth) should help avoid drought. In contrast, regrowth types that grow 6 to 8 in (15 to 20 cm) before water becomes unavailable are likely to have low levels of carbohydrates going into the winter. Drought at this time would be analogous to a hard frost in the fall that occurs before growth is adequate for stored reserves. In Montana, we recently selected both regrowth and nonregrowth types from a 50-year-old dryland alfalfa field with average precipitation of 13 in (32 cm). It may be possible to select plants that will regrow rapidly in years with extra water after first bloom but go dormant in other years.

One approach to determining which characteristics are most important for a dryland or rangeland alfalfa may be to develop divergent populations of alfalfa for many traits—for example, regrowth versus nonregrowth, heat tolerant versus nonheat tolerant, and tap versus fibrous root—from a common germplasm pool and to test these populations over a broad range of droughty conditions. Characterizing the populations that perform the best may allow us to determine which trait or traits are most closely related to drought resistance and should be selected for in a breeding program.

We are initiating this approach in Montana, even though we know the research will be time consuming, expensive, and there are no guarantees for success. We believe a truly superior drought-resistant alfalfa cannot be developed without a better understanding of the traits involved and their interactions.

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A Review

Information on the importance of diseases, insects, and other pests on rangeland alfalfa is sparse. Frequently, the information is observational and must be documented by properly designed investigations.

The distribution and importance of the various diseases, insects, and nematodes that attack alfalfa in the United States have been discussed (2). Some report that common leaf spot [Pseudopeziza medicaginis [Lib. Saac.], yellow leaf blotch [Leptotrichila medicaginis [Fckl.]], syn. Pseudopeziza jonesii [Nannf.]], spring blackstem (Phoma medicaginis Malbr. & Roum. var. medicaginis), summer blackstem and leaf spot (Cercospora medicaginis Ell. & Ev.), and rust (Uromyces striatus Schr.) are the most destructive foliar pathogens in dryland areas (9). Bacterial wilt [Corynebacterium insidiosum [McCull. H. L. Jens.]] may be important in low areas where moisture accumulates. Root and crown diseases are more prevalent in older stands, and viruses may be important under some conditions.

Of the various species of insects that attack alfalfa, the spotted alfalfa aphid (Theroiaaphis maculata Buckton), pea aphid (Acyrthosipon pisum Harris), alfalfa weevil (Hypera postica Gyllenhal), potato leafhopper (Empoasca fabae Harris), and several species of grasshoppers are considered important in dryland areas (9). Of these, grasshoppers are potentially the most important on rangeland. Outbreaks are most common in the Northern Great Plains, but the migratory characteristics of some species make grasshoppers a particularly destructive pest (16). There are many species of grasshoppers, but five species—the lesser migratory grasshopper (Melanoplus sanguinipes F.), the differential grasshopper (M. differentialis Thomas), the red-legged grasshopper (M. femur-rubrum De Geer), the two-striped grasshopper (M. bivittatus Say), and the clear-winged grasshopper (Camnula pellucida Scudder)—cause 90 percent or more of the damage to crops on cultivated lands (15). The relative importance of species changes as one species is replaced by another (18). An excellent review has been presented on forage losses caused by rangeland grasshoppers (6).

Some researchers have discussed the food habits and preferences of grasshoppers in the grasslands of the north-central Great Plains (10, 11). Some species of grasshoppers feed on many different plant species while others are very selective and feed on only a few. Some grasshoppers might even be considered beneficial because they feed primarily on undesirable forbs. Species that are destructive to cultivated crops may or may not be of importance in grasslands. For example, M. bivittatus and M. differentialis are not considered to be of economic importance in grasslands and M. femur-rubrum is only of limited importance. On the other hand, M. sanguinipes is polyphagous in its feeding habit and is one of the most destructive species on both grasslands and cultivated lands. M. packardii (Scudder) prefers legumes but is of limited importance. Schistocerca lineata (Scudder) has a definite preference for native legumes, and species that prefer native legumes also might be expected to attack alfalfa and other introduced legumes.

Grasshoppers have been controlled primarily by spraying with insecticides because little is known about resistance mechanisms or whether such mechanisms even exist in crop plants. To be effective, the control program must be initiated at the proper time and on all of the infested rangeland in an area. Which grasshopper species will be the most serious in rangeland can be determined by making an egg survey in the fall or spring and by observing the nymphs and adults of the different species during the spring and summer (13). With this method, proper control measures may be initiated later during the same year or in the following year.

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1 Joint contribution of the Agricultural Research Service, U.S. Department of Agriculture, and the Colorado State University Experiment Station, Fort Collins, Colo. 80523.
2 Research geneticist, Crops Research Laboratory, Colorado State University, Fort Collins, Colo. 80523.
3 Italic numbers in parentheses refer to Literature Cited, p. 14.

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Biological methods show considerable promise for grasshopper control. Of the parasites used, the protozoan Nosema locustae Canning has potential value (4, 5). One of the problems with this method, however, is the time required for the protozoan to reach population densities that will control the grasshoppers. N. locustae also was found compatible with a chemical insecticide, indicating that if insecticides could be used to reduce the existing grasshopper population, then N. locustae would keep the grasshopper population under control (12). Other recent studies have shown that species of rangeland grasshoppers were variable in their acceptance of the wheat bran bait that is used to distribute the insecticide and N. locustae (14). This finding suggests that various bait formulations of N. locustae and chemical insecticides might be used to control the many species of rangeland grasshoppers.

The general topics of breeding for disease, insect, and nematode resistance in alfalfa have been discussed (7, 8, 17). The importance of having multiple-pest resistance in rangeland alfalfa is not known, but the thin stands found in range seedings and the semiarid environment reduce the severity of most insect and disease pests. Introducing a legume into the rangelands, however, may cause certain species of insects, primarily grasshoppers, to increase. The effects that nematodes might have on the culture of rangeland alfalfa are not known.

Pocket gophers, which occur only in the Western hemisphere, probably present a greater hazard to alfalfa culture on rangelands than any other pest. Four species are found in Colorado: the mountain pocket gopher (Thomomys talpoides), the valley pocket gopher (T. bottae), the plains pocket gopher (Geomys bursarius), and the Mexican pocket gopher (Cratogeomys castanops). (1) Pocket gophers feed on both above-ground and below-ground plant parts, but the root system is damaged most. They prefer plants with large, fleshy roots (3). Alfalfa plants with creeping roots are damaged less than plants with taproots. The value of creeping-rooted alfalfa in rangeland infested with pocket gophers has not been established.

In range seedings in eastern Colorado, alfalfa seldom lasts longer than 10 years because of pocket gophers. Most control methods are not economical in rangelands, but the burrow-builder method, which consists of an artificially constructed burrow containing poisoned bait, may be the most promising. Assessing the true damage to alfalfa by gophers, rabbits, and other pests in small rangeland nurseries is difficult because such plantings attract pests from large areas.

Literature Cited

Origins Of Alfalfa Cultivars Used For Dryland Grazing
Melvin D. Rumbaugh¹

Introduction
The alfalfa cultivars and strains considered here were selected because of their intended use and areas of adaptation. I included only those specifically suggested by researchers or consumers as being well suited for range or pasture in semiarid and nonhumid temperate climates. The order of presentation is based in part on the type of roots and crowns and in part according to the chronology of introduction, licensing, registration, or release, with some adjustments for ease of discussion.

Root-Proliferating Alfas
*Medicago falcata*. The name 'Siberian' has been used to identify seed stocks and populations of *M. falcata* L. seeded on a limited acreage in the Northern Great Plains and included in experimental plantings in Western States and provinces. I believe that many of these, if not most, descended from introductions distributed by N. E. Hansen of the South Dakota agricultural experiment station between 1898 and 1937.

The following *M. falcata* accessions were collected during a 1906 expedition (19):

P.I. 20717 Kharkof Province, southeastern Russia
20718 Omsk, Siberia
20719 Omsk, Siberia
20720 Irkutsk, eastern Siberia
20721 Samara Province, Volga River region
20722 Saratov Province, central Volga River region
20724 Tomsk, Siberia
20725 Don Province, lower Volga River region, southeastern Russia
20726 Samara Province

This listing was repeated in a later publication (20). Hansen’s collections in a 1908 trip included the following:

P.I. 24452 Western Siberia (Hansen called this his ‘Obb Siberian’) 24453 Western Siberia (named ‘Omsk 1908 Siberian’ to differentiate it from P.I. 20718 and 20719, although Hansen considered them to be agronomically similar)
24454 Eastern Siberia (collected north of Irkutsk near the western shore of Lake Baikal)
24455 Siberia (collected along the Irtysh River, 10 miles north of Semipalatinsk)
24456 ‘Siberian alfalfa’ (collected in the Gobi Desert in Manchuria)

Three accessions were obtained from previous introductions:

P.I. 27268 Selection from Hansen’s plot of P.I. 24452 from Siberia
27375 Kerkof (propagated from cuttings of P.I. 20717)
27394 Samara, Russia (a seed increase from P.I. 20721)

Two other accessions of considerable importance were from seeds collected by a contact in Russia and mailed to Hansen. These were:

P.I. 28070 Semipalatinsk, southwest Siberia
28071 Orenburg Province. This M. falcata cannot be considered as originating in Siberia but is similar to the 'Siberian' strains in adaptation. Hansen described it as having a small proportion of blue-flowered plants.

Seed and plants of these stocks were distributed widely for many years. In 1912, for example, seeds of nine accessions were advertised for sale by the South Dakota Agricultural Experiment Station. Three of these were 'Siberian' alfalfas; one was called 'Semipalatinsk', which might also be 'Siberian', and an additional offering was M. falcata from Samara. Seeds of 'Semipalatinsk' were distributed as recently as 1922. Hansen described the strain as having the strongest growth of the *M. falcata* collections (22).

Rooted plants were also disseminated in large quantities. More than 50,000 were shipped to one recipient, and this practice continued at least as late as March 20, 1920. On that date, an order was filled for plants of both 'Cossack' and 'Orenburg'. An old price list shows that 'Semipalatinsk' seed was sold at $5.00 per pound and 1-year-old plants of 'Cossack' were sold by mail, postpaid, for $1.00 per hundred (15). The distribution of Hansen’s introductions and their use in cultivar development have been described (40).

Publications of the period indicate that any *M. falcata* might have been described as 'Siberian' alfalfa by some authors. In one classification of alfalfas, the authors (37) attempted to correct this by explaining, “In a fifth group are included the various forms of the yellow-flowered species, sometimes referred to as 'Siberian' alfalfas. This term, however, is misleading since not all of the yellow-flowered alfalfas come from Siberia.”

All known root-proliferating cultivars now used are related to one or more of Hansen’s introductions. This trait was first described in a publication after the discovery was made in a nursery at Highmore, S. Dak., in 1912 (36). The annual report for that season states, “Many plants of S.D. 55 at Highmore show peculiar root systems. Laterals from the main roots of plants often extend for a distance of from 30 to 36 inches, then send stems to the surface. These laterals, parallel to the surface, are from 6 to 10 inches below the surface” (13 p. 64). S.D. 55 is known to be an increase of P.I. 28071, the accession of *M. falcata* collected from Orenburg. One year later, the same trait was found in P.I. 24455 from Semipalatinsk (14). A third strain exhibiting the trait was referred to in a 1914 annual report, which states, “This root characteristic has now been found in P.I. 28071, 24455, and 28070” (15). One other accession from Orenburg, P.I. 23625, was similar to P.I. 28071 (36). I believe all modern root-proliferating cultivars are derived in part from at least one of these four strains. The contributions of the germplasm collected by Hansen to recently developed cultivars have been described in great detail (40).

¹ Research geneticist, Agricultural Research Service, U.S. Department of Agriculture, Utah State University, Logan, Utah. 84332.
² Italic numbers in parentheses refer to References, p. 18.
'Siberian' alfalfa is grown for forage on a limited scale in the western Dakotas. Fields designated as 'Orenburg' remain in hay production in Wyoming and Montana. Seeds of these strains have been used for range and pasture experiments. The 'Siberian' strain tested on a mountain range in Utah was found to be inferior in persistence and forage yield to 'A-169', 'Ladak', and 'Rhizoma' (7). Others determined that a strain of 'Siberian' obtained from near Coal Springs, S. Dak., persisted and was productive 23 years after planting at a lower elevation than the Utah experiment (41, 43). Numerous dryland seedings of M. falcata in Montana have been summarized (16). In some trials, the M. falcata was identified as 'Orenburg' and in others as 'Ladak'. 'Semipalatinsk' was the most productive alfalfa tested in a dryland experiment conducted between 1953 and 1963 in eastern Oregon (45).

'Rambler'. The first root-proliferating cultivar of alfalfa was bred (32) and released in 1955 (26). The early breeding program leading to its development has been described (25).

'Rambler' is a seven-clone synthetic with parentage tracing to the cultivar 'Ladak' and 'Rhizoma' and to a Siberian strain of M. falcata L., introduced to North America by Hansen. The 'Ladak' and 'Siberian' seed stocks were planted at the research station, Swift Current, Saskatchewan, in 1934, and were subjected to intensive natural selection through several years of severe drought and winterkill. Surviving 'Siberian' plants were selected on the basis of root proliferation and upright growth habit; 'Ladak' plants were selected for high seed yield. The clones retained were further evaluated by agronomic trials of their selfed, backcross, and controlled-cross progenies.

'Rhizoma' and 2,300 related plants were established in 1940, but only 45 survived the unusually harsh winter of 1940-41. Several of these were crossed with chosen plants of the 'Siberian' populations, and their progenies were used for further selection. After examining 10,000 plants for root proliferation in 1947, the selections subsequently were tested for combining ability.

Between 1949 and 1951, a number of experimental synthetics were formed and tested. The best among these was named 'Rambler'. The seven parental clones have the following origins:

3 clones: 'Ladak' X ('Ladak' X 'Siberian')
2 clones: ('Ladak' X 'Siberian') X ('Ladak' X 'Siberian') 'Ladak'
1 clone: ('Rhizoma' X 'Ladak') X 'Siberian' ('Ladak' X 'Siberian')
1 clone: 'Siberian' ('Ladak' X 'Siberian') X 'Siberian' ('Ladak' X 'Siberian')

None of the parental plants were related; hence, the genetic base of the cultivar is quite broad.

'Travols'. This root-proliferating cultivar was derived from germplasm introduced by Hansen and subjected to natural selection for many years in two environments. An undetermined number of the 10 parental clones were selected from among progenies tracing to seed stocks obtained in 1948 from Canadian scientists. These seed stocks were from the 'Ladak'- 'Siberian' population, which ultimately gave rise to the cultivar, 'Rambler' (42, 44).

A search of old alfalfa fields resulted in the discovery of eight root-proliferating hybrid plants in Perkins County, S. Dak. (1). Adjoining fields of 'Cossack' and 'Semipalatinsk' (P.I. 24455) were sown in 1912 with seed from Hansen. Introgression occurred, and the root-proliferating plants found in the 'Cossack' stand in 1950 were distinct, morphologically, from the noncreeping forms (2). Each was 3 to 4 ft (90 to 120 cm) in diameter, markedly delayed in recovery height, yellow or variegated flowered, and sickle podded. These plants were included in the breeding effort, which ultimately resulted in the release of 'Travois'.

The selection process emphasized lateral spread by root proliferation, growth habit, rapid recovery following cutting, and resistance to bacterial wilt and to foliage and stem diseases.

'Roamer'. This seven-clone, creeping-rooted, synthetic cultivar was also developed in Saskatchewan (27, 28). Parental background included strains of M. falcata and the cultivars ‘Cossack’, ‘Hardistan’, ‘Ladak’, ‘Rambler’, ‘Ranger’, and ‘Rhizoma’. The breeding method was based on selecting desirable plants grown in spaced plantings, intercrossing them, growing progeny lines, selecting within the best of these polycross-progeny, testing the selections, and then using the best parent plants to form the synthetic (37). Flowers are strongly variegated, and the seed pods have one and one-half to three loose coils. 'Roamer', winterhardy and drought resistant, was licensed for sale in Canada in 1966.

'Drylander'. Tested under the experimental designation of Sc. Syn. 3651, this yellow-flowered alfalfa, M. media Pers., was developed at the research station at Swift Current and licensed in 1971 for use in Canada (29). It is a synthetic from 15 yellow-flowered clones selected from a large number in old breeding nurseries that had been overseeded with bromegrass. Traits considered included longevity, creeping rootedness, competitive ability, seed set, and resistance to pod shattering. Additional clonal trials for seed yield and disease resistance were followed by progeny tests for creeping rootedness and winterhardiness.

Approximately 70 percent of the plants of 'Drylander' are creeping rooted. This is 10 percent more than 'Rambler' or 'Roamer'. 'Drylander' is more winterhardy than 'Rambler' or 'Roamer' and as tall as 'Rambler'. Sixty-eight percent of the plants of this cultivar were not diseased in a bacterial wilt trial. Seed production averaged 78 percent of 'Vernal' in Canadian tests with leaf-cutter bees as pollinators. This was less than the seed yield of 'Rambler' or 'Roamer'.

'Drylander' is well adapted for hay and pasture use on dryland in the Canadian Prairie region (30); competes well with crested wheatgrass, Agropyron cristatum (L.) Gaertn, and with Russian wildrye, Elymus junceus Fisch.; and is recommended in Canada as a mixture component with these grasses.
'Kane'. Creeping-rooted plants from the research station at Swift Current were crossed with wilt-resistant plants from the station at Saskatoon in 1952. Spaced plant nurseries of $F_1$, $F_2$, from intercrossed $F_1$ plants, and backcross progenies, were established at Lethbridge in 1952, 1955, and 1956. Selection for the creeping-rooted habit of growth, recovery after cutting, vigor, and resistance to bacterial wilt was followed by polycross progeny tests in 1959 to 1963. Six $F_2$ clones with high combining ability were the parents of experiment strain Syn. LC-B tested from 1965 to 1970 and licensed as 'Kane' in 1971 (17, 18).

'Kane' yielded 4 percent more forage than 'Roamer' over 42 station years at 10 locations in western Canada. Winterhardiness and wilt resistance were equal to or better than those of 'Roamer'. Seed yield with leaf-cutter bees averaged less than 'Beaver', 'Ladak', 'Rambler', or 'Roamer'. Sixty percent of the plants of 'Kane' showed some expression of the creeping-rooted character in spaced plantings or thin stands. Flower color is predominantly blue and purple but includes various shades of yellow and variegated types.

'Roverde'. This is a cultivar merchandized by the L. Teweles Seed Company. Breeding and parentage are unrecorded, but descriptions of the cultivar are similar to that for 'Travois', and it is believed to be a variety cross of 'Travois' × 'Teton'.

'Spredor'. This is a proprietary cultivar bred by the research staff of Northrup, King and Company, and approved for certification in 1974. It was developed by intercrossing and selecting for persistence, wilt resistance, and vigor, with emphasis on developing root proliferation in a high percent of the population. Original parentage traces to four clones from the cultivar 'Travois', one from 'Rambler', one from 'Vernal', and one M. sativa from Arabia, P.I. 183262.

'Spredor' was intended primarily for overseeding rangeland and for use in permanent or semipermanent pastures. Area of adaptation is reported to be the Central and Northern United States and Southern Canada (4). Plants of this cultivar have highly variegated flowers, low set crowns, a prostrate or semiprostrate growth habit, and early fall dormancy. 'Spredor' is resistant to bacterial wilt. An improved cultivar, 'Spredor 2', with superior seed-yield potential, will be marketed by Northrup, King and Company in 1981.

'Cancreep'. The breeding program, which resulted in the cultivar 'Cancreep', was initiated in 1954 by H. Y. A. Daday of the Commonwealth Scientific and Industrial Research Organization (CSIRO) Division of Plant Industry in Australia. The goal was to combine the creeping habit and underground stem crown of 'Rambler' with the summer and winter vigor of 'Hunter River', 'Hairy Peruvian', and 'African' (5). Twenty-five creeping-rooted plants selected from 400 plants of 'Rambler' and 5 clones obtained from Swift Current were crossed with 20 plants selected from a population of 3,000 plants of 'African', 'Hairy Peruvian', and 'Hunter River'. The $F_1$ plants were intercrossed and backcrossed to 'Rambler' (8). These progenies formed the basic germplasm pool subjected to the combination of family and individual selection that resulted in the cultivar 'Cancreep' (9).

In Australia, 70 percent of the plants of 'Cancreep' show the creeping trait. It has yielded more forage in temperate climates than 'Hunter River' and is an equally prolific seed produce. Survival is superior to any of the parents. 'Cancreep' performed poorly in regions with hot, dry summers or with a subterminal climate (10).

'Victoria'. 'Victoria' has been described as producing "wide, low crowns, a much-branched taproot with an inherent capacity to spread by means of creeping roots or rhizomes, a large number of relatively small stems per crown, and a semi-decumbent growth habit" (38). It is a nine-clone synthetic, tracing to the following source materials:

- two clones: Canada Ma 5110
- two clones: Canada Sc 3513
- one clone: Canada ScMa 531
- one clone: Nebraska A224
- two clones: 'Rhizoma'
- one clone: unknown

These parents were selected on the basis of polycross and $S_1$ progeny performance from among 50 clones chosen from source nurseries of 300 creeping-rooted or rhizomatous plants.

The suggested area of probable adaptation includes all or part of the States of Arkansas, Oklahoma, Kansas, Missouri, Illinois, Indiana, Kentucky, and Tennessee.

Rhizomatous Alfalfas

'Severla'. Limited information about this strain was published by Hanson et al. (24). It is a selection from an old stand in the dryland area of southern Idaho, and detailed history of its origin was written (6). Hansen sent seed samples of numerous alfalfas to A. E. Yoder, who homesteaded on the Sunnyside Desert in 1908. The seeds were planted on a site that received less than 10 in (25 cm) of annual precipitation. Three populations, 'Grimm', 'Orenburg', and 'Semipalatinsk', appeared to be outstanding. These three were allowed to cross-pollinate and oil progeny performance from among 50 clones chosen from source nurseries of 300 creeping-rooted or rhizomatous plants.

The suggested area of probable adaptation includes all or part of the States of Arkansas, Oklahoma, Kansas, Missouri, Illinois, Indiana, Kentucky, and Tennessee.

The growth habit of 'Severla' plants is quite variable. They range from upright to procumbent, and flower color is extremely variegated. Some plants do show considerable rhizome development under dryland conditions. 'Severla' is believed to be less winterhardy than 'Ranger' but is quite drought resistant. It is best adapted to dryland range and pasture in the western States. In 1958, the estimated acreage of 'Severla' comprised less than 0.01 percent of the total U.S. alfalfa plantings, and its use has declined since that time.

'Nomad'. The origins of this cultivar are somewhat obscure. It was developed from persistent alfalfa plants growing on a Klamath County, Oreg., dryland farm at 4,500 ft (1,350 m) elevation, where precipitation averaged 11 in (27.5 cm) per year (24).
The field where the 'Nomad' source material was found was seeded to alfalfa in 1918 (33). By 1925, the stand was believed gone, and the field was plowed and cropped for 17 years. W. F. Cyrus selected surviving plants for creeping habit, leafiness, seed set, and hardiness after the E. F. Burlingham Seed Company took over the farm in 1943.

Plants of 'Nomad' are hardy but susceptible to bacterial wilt. Some have well developed rhizomes that enable the plants to spread in certain environments. Forage and seed yields are relatively low under good growing conditions. This cultivar often is recommended for use in range revegetation programs. No seed of 'Nomad' was available from the originating company in August 1977 (39).

'Rhizoma'. 'Rhizoma' is a broad-crowned, wilt-susceptible, variegated cultivar developed at the University of British Columbia, Vancouver, by mass selection from a cross between 'Grimm' and a yellow-flowered alfalfa identified as 'Don' (35). 'Rhizoma' was released in 1947 (24) under the Canadian license number 483.

'A-169'. This is an Alfalfa Improvement Conference designation for Nebraska experimental population 03-603. The population was based on hybrids involving M. falcata, M. glutinosa, a Turkistan selection, and a spreading alfalfa from Turkey. P.I. 107298. 'A-169' yielded more forage than 'Ladak', 'Rhizoma', or 'Siberian' in a 15-year-old high-altitude test in Utah (7).

'A-224'. This cultivar is a synthetic of four clones with a spreading or rhizomatous growth form. The clones were selected by the Alfalfa Improvement Conference from the breeding programs in Pennsylvania (C87), Iowa (C63), and Nebraska (C53, C130) (46). Origins of the clones as recorded (47) were as follows:

C53 A wilt-resistant survivor from the polycross progeny of another clone, C8, which itself was a wilt-resistant survivor from seed from a natural crossing block involving hybrids between a spreading introduction from Turkey (P.I. 107298), a 'Ladak' selection, M. falcata (P.I. 69137), and M. glutinosa.

C63 A rhizomatous selection from Woodside Golf Course, Des Moines, Iowa.

C87 A selection from the Nebraska single cross 1124 × 1128.

C130 A wilt-resistant survivor from the polycross progeny of clone C11. C11 was a F1 of a cross between a selected 'Ladak' plant with cream-colored flowers × (selection from an old Turkistan field × Cossack).

'A-224' yielded more hay than 'Nomad' or 'Seveira' but less than 'Rhizoma' when tested under dryland conditions in northeastern Wyoming (34). It was the highest yielding of the four cultivars at the Archer station in southeastern Wyoming.

'Teton'. In 1914, Hansen made an interspecific cross of two of his alfalfa collections. The M. sativa L. parent was described as Hansen's 'Select Turkestan' (P.I. 20711) from Tashkent in Russian Turkestan. The M. falcata L. parent was Hansen's yellow-flowered 'Siberian' alfalfa (P.I. 24455), which he collected as seed from wild plants near Semipalatinsk in Siberia (2, 23). A spaced-plant nursery was established in which some plants survived until 1949. At that time, certain survivors were selected for a breeding program.

Clonal and progeny testing for resistance to bacterial wilt and to common leafspot, low wide crowns, vegetative vigor, and seed yield led to a four-clone synthetic released in 1958. 'Teton' was intended to be used for either hay or grazing. In South Dakota, it appeared to persist under grazing better than 'Nomad' or 'Rhizoma' and to develop more and longer rhizomes than 'Rhizoma'.

'College Glutinosa'. This cultivar was cited as being similar in rhizome development to 'Rhizoma', 'Nomad', 'Seveira' and 'Teton' (11). The name implies at least partial origin from M. glutinosa.

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