Forage Legumes
[SECOND EDITION]

Clovers, Birdsfoot Trefoil, Cicer Milkvetch, Crownvetch and Alfalfa

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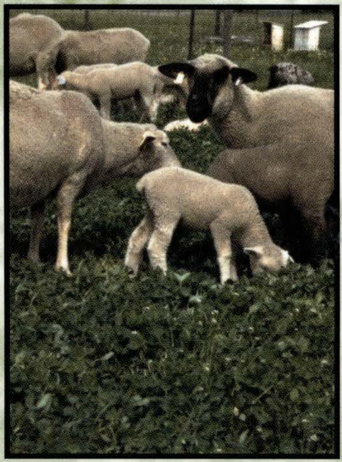

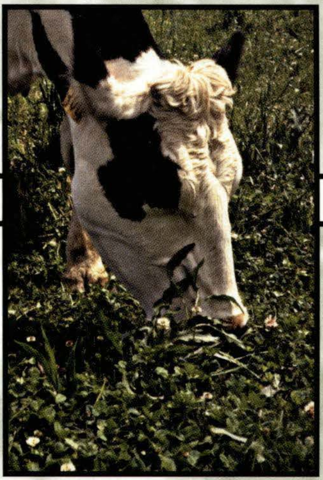

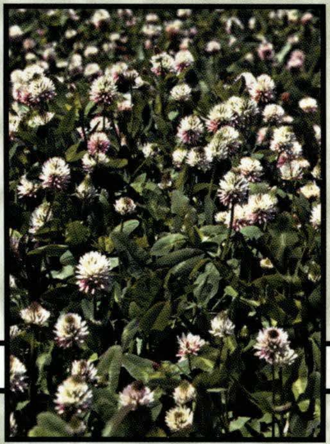

Minnesota Agricultural Experiment Station

UNIVERSITY OF MINNESOTA

Station Bulletin 608–2003

Produced with Financial Assistance from the USDA Sustainable Agriculture Research and Education Program and from Norfarm Seeds, Inc.

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Editors

Craig Sheaffer, Nancy Ehlke and Paul Peterson are agronomists with the University of Minnesota Department of Agronomy and Plant Genetics, Saint Paul, Minnesota. Kenneth Albrecht is with the University of Wisconsin's Department of Agronomy.

Acknowledgements

This publication is a revision of Minnesota Agriculture Experiment Station Bulletin 597-1993, *Forage Legumes,* originally issued in 1993.

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Produced by Communications and Educational Technology Services
University of Minnesota, Saint Paul, Minnesota 55108-6068

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FOREWORD

USING THIS PUBLICATION

This publication is intended to serve as both an educational resource for students and a reference tool for agricultural professionals such as crop consultants, extension educators and farm producers. To make this easier to use, some material is repeated in more than one section.

Tables 1 through 3 are in the introductory section because they are specific to that general discussion. For similar reasons, tables 25 and 26 are within the section on cultural practices.

Other tables, whether specific to a single forage species or incorporating data for many, are grouped in a common appendix which begins on page 36.

This second edition revision features a new extended section on kura clover, a forage legume relatively new to U.S. agricultural producers, which has growth, persistence and nutritional qualities which the authors believe make it extremely attractive for growers in the north central region of the United States. Also, sainfoin has been eliminated from this revision because it is rarely planted in the region.

LEGUME NAMES

Like many plants, legumes often have both common and scientific names. Common names that evolve over centuries are sometimes recognized only in limited geographic areas. For example, alfalfa is called lucerne in most of Europe, Australia, and New Zealand. It has also been called purple medic or Chilean clover. And, Wendelin Grimm, the German immigrant who developed the parent stock of 'Grimm' alfalfa in Carver County, Minn., referred to it as the everlasting clover, the "ewiger Klee."

A scientific naming system developed by Swedish botanist Linnaeus, in the 1700s, allows for worldwide identification and communication about plants. In that system, common names are replaced with names based on Latin, which are usually written in italic. These scientific names are composed of two italicized Latin words: the first word names a plant's genus (a larger biological class of plants with common characteristics) and the second identifies its species (a subdivision of plants potentially capable of interbreeding).

Complete scientific names also include the names of individuals (often abbreviated) who first identified a given species. For example, the scientific name of alfalfa is *Medicago sativa* L. The abbreviation "L" indicates that Linnaeus, who developed this notation system, first described the species. In this publication, we provide the scientific names of specific legumes in addition to common names.

Forage Legumes [Second Edition]

Clovers, Birdsfoot Trefoil, Cicer Milkvetch, Crownvetch and Alfalfa

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INTRODUCTION

Forage legumes belong to the legume or bean family (Fabaceae or Leguminosae). Members of this large family (more than 16,000 unique species) are characterized by having seeds born in pods, compound leaves with multiple leaflets, and root associations with bacteria that allow for symbiotic nitrogen fixation. Legumes produce seeds and foliage that are usually rich in protein with a desirable amino acid composition.

Legumes are second only to grasses in importance to human and livestock nutrition. The legume family includes well known, large seeded plants like beans, peas, peanut and soybean that are mostly used for seed (called a pulse) production, as well as small seeded legumes such as the clovers, birdsfoot trefoil and alfalfa that produce herbage for harvesting as forage.

LONG HISTORY AND VARIED USES

Edible legume grains have been domesticated and used by civilizations for centuries as a dietary source of protein. For example, soybean, native to eastern China, was described more than 5,000 years ago as one of the five sacred grains vital to their civilization. Historical records indicate similar early importance for legume forage crops. Roman records note that alfalfa was introduced into Greece from Persia, by the Medes about 500 years before the common era, as a feed for chariot horses.

Forage legumes continue to be valuable crops throughout the world and especially in the north central region of the United States. They are integral components of sustainable agricultural systems, providing high quality livestock feed, nectar, seed, green manure, and soil cover.

In the north central region of the United States, forage legumes are mostly used for livestock feed and are an essential component of most cattle and sheep rations. They are biologically harvested by grazing livestock, or mechanically harvested following drying and stored as hay or silage.

Because of their growth habits, forage species vary in their suitability for use as grazing or hay. For example, the prostrate growth habits of kura clover and white clover make them especially adapted to grazing systems, whereas the upright growth habit of alfalfa makes it better suited as a hay crop. When used for grazing, forage legumes are often grown in mixture with perennial grasses such as smooth bromegrass, timothy, and Kentucky bluegrass.

Legumes are also well known as soil building plants, and their use for that extends far back in history. They enhance soil quality by adding organic matter, and improve soil structure and water infiltration. Earthworm populations are usually greater in fields planted to perennial forages than in fields planted to annual row crops.

Early Roman writers on agriculture, such as Pliny and Virgil, recognized the value of using legumes like peas and beans and vetches to replace manure. Later, in Colonial America, when farmers were exhausting their soils by continuously cropping tobacco, wheat and corn, Thomas Jefferson promoted the use of red clover in rotations for improving the soil.

LEGUME LIFE CYCLES

The terms annual, biennial, or perennial are used to describe the time required for legumes to complete their life cycles. An annual legume like soybean germinates from seed, flowers, sets seed and dies within one growing season. In contrast, once established, perennial plants like alfalfa and kura clover live for three or more years, and have potential to set seed each year. An intermediate group of legumes, biennials such as sweetclover, live for two years. These grow vegetatively the first year, and flower and die in the second year.

Of the three life cycle types of legumes, perennials are considered to be the most valuable for the environment. They provide continuous ground cover, recycling of nutrients, and long-term carbon storage. The use of perennials also eliminates the need for annual reseeding.

NITROGEN FIXATION

Properly managed forage legumes are nitrogen self-sufficient. These plants can achieve vigorous growth without the nitrogen fertilizers that are required for grasses. This self-sufficiency is achieved through the process of biological nitrogen fixation.

Legumes convert otherwise unusable atmospheric nitrogen (N_2, which is 78 percent of the earth's atmospheric gases by volume) into ammonia and ultimately into nutritionally valuable plant protein. Symbiotic nitrogen fixation is a partnership between the legume plant and Rhizobia bacteria that actually perform the nitrogen conversion. In exchange, the legume plant supplies nutrients and energy the bacteria require for their growth and function.

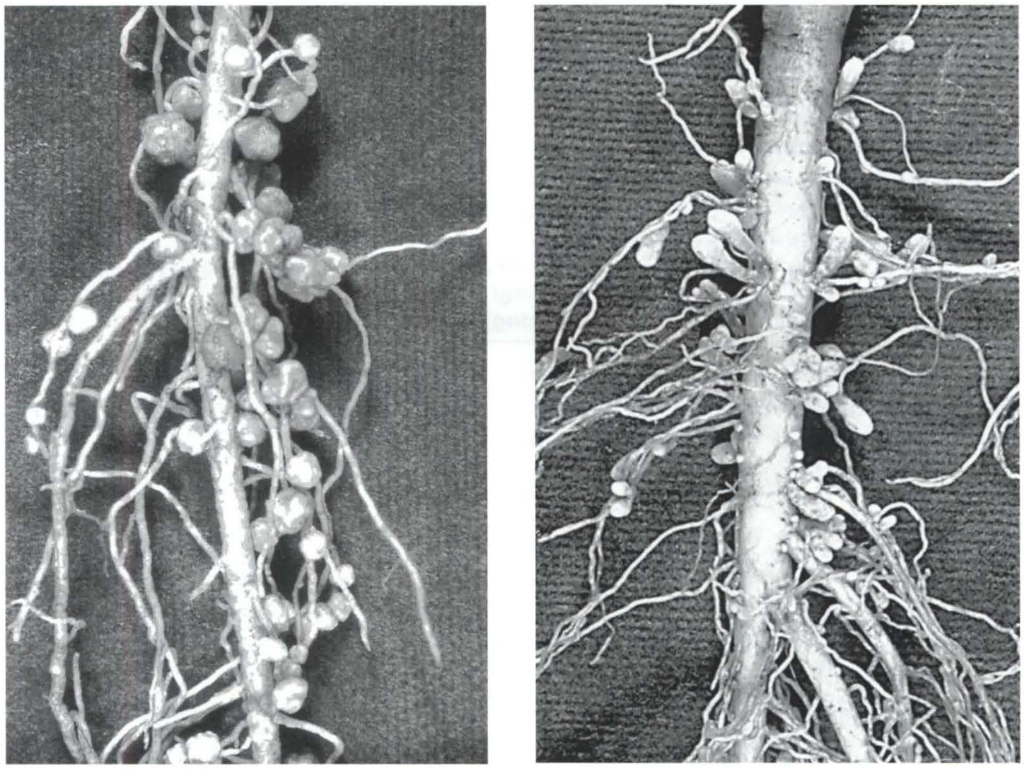
Rhizobia that are present in the soil, or supplied with inoculum to the seed, infect plant root hairs and stimulate development of tumor-like nodules on the roots (figure A). Nodule shapes vary and can be elongated lobes as found in roots of alfalfa and the clovers, or round like those found on birdsfoot trefoil roots. Lobed nodules will overwinter and fix nitrogen for more than one growing season while round nodules die and reform on roots each year. A specific Rhizobium is required for a legume species. For example, bacteria infecting and nodulating kura clover will not effectively nodulate alfalfa. Upon dissection, active regions of nodules will be observed to contain a pink pigment, leghemoglobin, that is indicative of active nitrogen fixation.

Nitrogen fixation by healthy plants causes legume foliage and seed to both be consistently rich in protein. In addition to requiring no synthetic or organic nitrogen fertilizer for growth, protein and nitrogen rich legume plants can be plowed under to supply nitrogen to subsequent crops in rotations. Productive stands of legumes like alfalfa usually meet all the nitrogen requirements for a subsequent corn crop. In a traditional Midwestern crop rotation, a legume can be grown and harvested for two or more years, and then incorporated into the soil and followed by a corn crop.

In managing a legume like alfalfa, red clover or sweetclover as a green manure crop for plow down, the amount of fixed nitrogen contributed to the soil depends on the quantity of nitrogen-rich forage incorporated. Alfalfa herbage typically contains from 3 to 3½ percent nitrogen depending on its maturity, while roots contain only about 2½ percent nitrogen. That is why green manure systems usually allow a significant amount of herbage to accumulate in the fall before incorporation.

Figure A. Well nodulated roots shown on two representative legumes.

(a) Birdsfoot trefoil *(b) Red clover*



Nitrogen fixed by legumes also helps grasses growing in mixture with them. The nitrogen transferred represents, on average, about half (but ranges from 20 to 80 percent) of a grasses needs, but the amount can be greatly influenced by soil nitrogen status and the legume composition of the stand. Legume nitrogen is transferred by root exudation, decomposition of decaying leaves, roots, and nodules, and by mycorrhizal fungi growing in association with grass roots. Transfer of legume nitrogen to grasses also occurs when nitrogen excreted in the urine or feces of grazing livestock is taken up by pasture grasses.

Legumes vary in the amount of atmospheric nitrogen they can fix. This variation is in part due to the relative effectiveness of the symbiosis between plants and the bacteria. Efforts are underway to select bacteria that are more effective at nitrogen fixation. The range of fixation shown in table 1 for a given legume species can be due to variations in soil and environmental conditions where measure-

Table 1. Quantities of nitrogen fixed by various legumes. [a]

Legume	Nitrogen Fixed (pounds/acre/year)
Alfalfa	70-200
Birdsfoot trefoil	44-150
Crownvetch	98
Cicer milkvetch	140
Crimson clover	57
Hairy vetch	99
Kura clover	17-158
Lentil	149-168
Red clover	60-200
Soybean	20-200
Sub clover	52-163
Sweetclover	120
White clover	115-180

[a] Source: Heichel (1987); Date and Brockwell (1978); Seguin, et al. (2000).

ments were taken. For example, nitrogen fixation is likely to be less for a legume grown on soil naturally high in nitrogen because legumes will fix less atmospheric nitrogen if soil nitrogen is available.

Forage legume species also differ both in their adaptation to soil and climatic conditions and in their susceptibility to insect damage and diseases. As a result, each of the various types of legumes have characteristics that often suit it best for specific uses (tables 2 and 3). This is why being able to identify, use and manage the perennial forage legumes commonly grown in the north central region can be valuable to a livestock producer.

Table 2. Characteristics of forage legumes. [a]

	Tolerance to								
Legume	Heat/ drought	Wet	Winter injury	Frequent cutting/ grazing	Soil salinity	Soil acidity	Soil alkalinity	Seedling vigor	Ruminant bloat inducing
Alfalfa	E	P	G	F	F	P	F	G	Yes
Alsike clover	P	E	P	P	F	G	G	G	Yes
Birdsfoot trefoil	F	E	F	G	F	G	G	P	No
Cicer milkvetch	G	F	E	F	F	F	E	P	No
Crownvetch	G	P	F	P	F	G	P	P	No
Kura clover	F	G	E	E	F	F	F	P	Yes
Red clover	F	F	F	F	F	G	P	E	Yes
Sweetclover	E	P	E	P	G	P	E	G	Yes
White clover	P	G	F	E	F	G	P	G	Yes

[a] E = excellent, G = good, F = fair, P = poor.

Table 3. Relative importance of insect and disease pests of forage legumes. [a]

	Insect pests				Diseases					
	Potato leaf hopper	Plant bugs	Leaf feeders	Crown and root feeders	Damping off	Crown and root rots	Vascular wilts	Foliar disease	Viruses	Nematodes
Alfalfa	3	2	2	2	2	3	3	2	1	2
Alsike clover	2	1	1	3	2	3	1	2	3	2
Birdsfoot trefoil	1	2	1	2	2	3	1	2	1	2
Cicer milkvetch	1	1	1	1	1	1	1	1	1	1
Crownvetch	1	1	1	1	1	2	1	2	1	1
Kura clover	3	1	1	2	2	1	1	2	2	3
Red clover	1	1	1	3	2	3	1	3	2	2
Sweetclover	1	1	2	3	2	3	1	1	2	1
White clover	2	1	1	2	2	3	1	2	3	3

[a] 1 = infrequent problem, 2 = occasional problem, 3 = frequent problem.

IDENTIFYING PERENNIAL LEGUMES

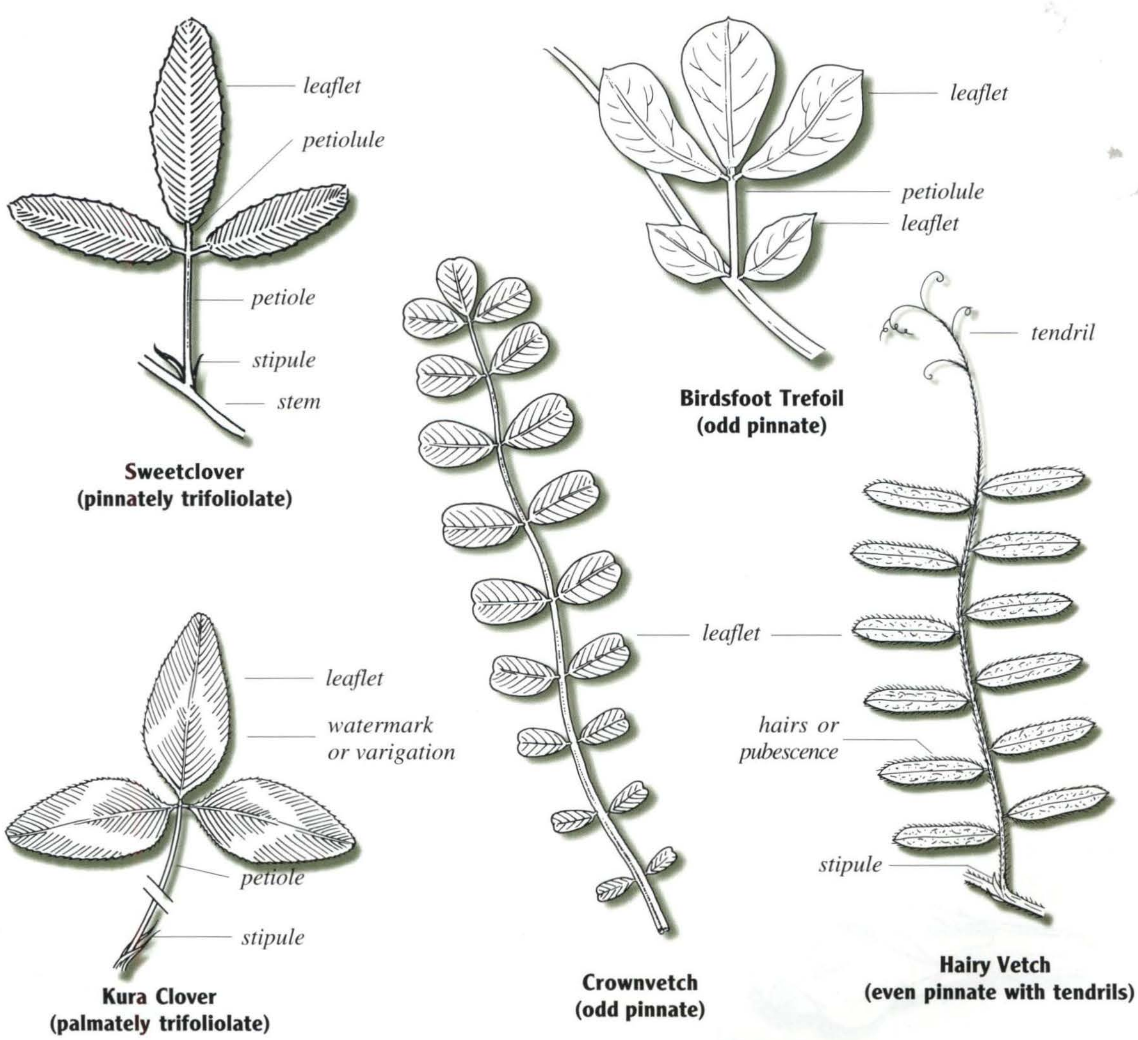
LEAVES

Leaf traits can be used to identify individual legume species. Legume leaves are compound (more than one leaflet per leaf) and often have large stipules. The leaves are borne on petioles which are attached to stems (figure B).

Though leaves of clovers and alfalfa typically have three leaflets per leaf, they sometimes have four or five. The frequency of four or more leaflets per leaf is influenced by both the genetic makeup of the plant and the growing environment. Because they occur relatively infrequently, "four leaf" clovers are said in folk lore to impart good luck.

Four arrangements, or organizations, of leaflets are found on the leaves of legume species that are commonly grown in the north central region of the United States. These are palmately trifoliolate, pinnately trifoliolate, odd pinnate and even pinnate with tendrils.

Figure B. Legume leaves are compound (more than one leaflet/leaf) and often have large stipules. The leaves are borne on petioles which are attached to stems. Typical leaf arrangements are shown (sizes are not to scale).



- Palmately trifoliolate – red, white, alsike, and kura clover;
- Pinnately trifoliolate – alfalfa and sweetclover;
- Odd pinnate – birdsfoot trefoil, crownvetch and cicer milkvetch;
- Even pinnate with tendrils – hairy vetch.

FLOWERS

Legume flowers are usually showy and colorful. These features enhance the plants' ability to attract its insect pollinators. Legume flower parts are the standard (also called the banner), wings and keel (figure C). The keel surrounds the male and female sexual parts.

Legume flowers are borne in groups called inflorescences (figure D). The most common legume inflorescences are the head (in red, white, alsike and kura clover), raceme (alfalfa, sweetclover and cicer milkvetch), and umbel (birdsfoot trefoil and crownvetch). A head will typically contain many flowers while racemes and umbels contain few.

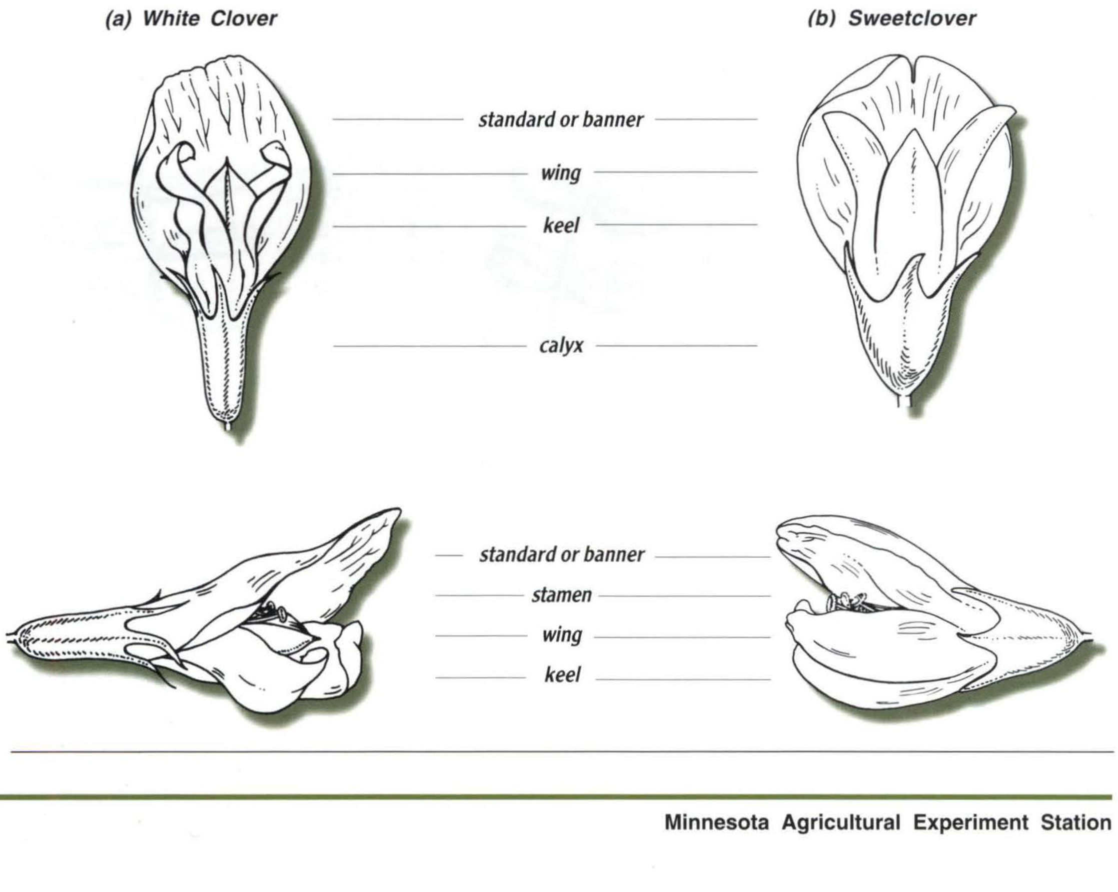
After pollination, legume seeds develop in pods. The pods can contain several seeds, as in birdsfoot trefoil, or only one seed, as in sweetclover. Northern Minnesota provides proper conditions for plant growth, pollination and seed harvesting. Thus, it is the site of an agricultural industry focused on commercial production of birdsfoot trefoil and clover seed.

ROOTS

Forage legumes are usually tap-rooted plants that have fine secondary roots produced from the tap root. It is these secondary roots that are usually nodulated by nitrogen fixing bacteria. This is illustrated for birdsfoot trefoil and red clover in figure A.

A very large tap root gives legumes such as alfalfa, kura clover and sweetclover greater drought tolerance than other forage legumes. In contrast, the more fibrous and shallow root systems of other legumes, such as white and alsike clover, reduce their drought resistance.

Figure C. Legume flower parts: the standard, wings, stamen and keel.



STOLONS AND RHIZOMES

Stolons are horizontal above-ground stems (figure E). Rhizomes are horizontal below-ground stems. Stolons and rhizomes allow for vegetative reproduction without seeds. New stems and roots can arise from nodes on stolons and rhizomes. This enhances plant persistence while creating more root sites for nodule growth. Stolons are found in white clover; rhizomes are found in kura clover, cicer milkvetch, and crownvetch. Legumes with rhizomes are among the most persistent species.

Figure D. Typical compound inflorescences of legumes (sizes are not to scale).

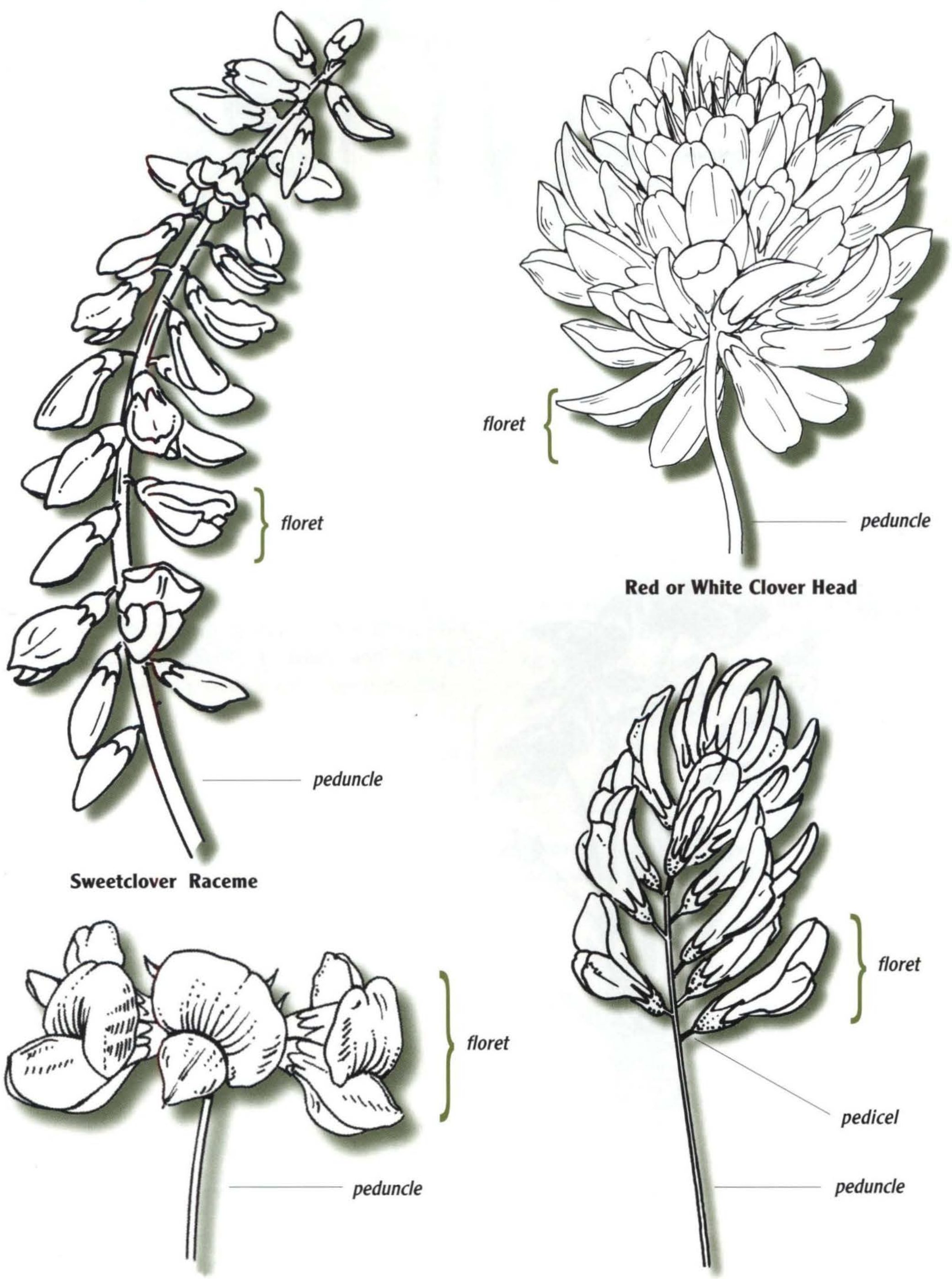
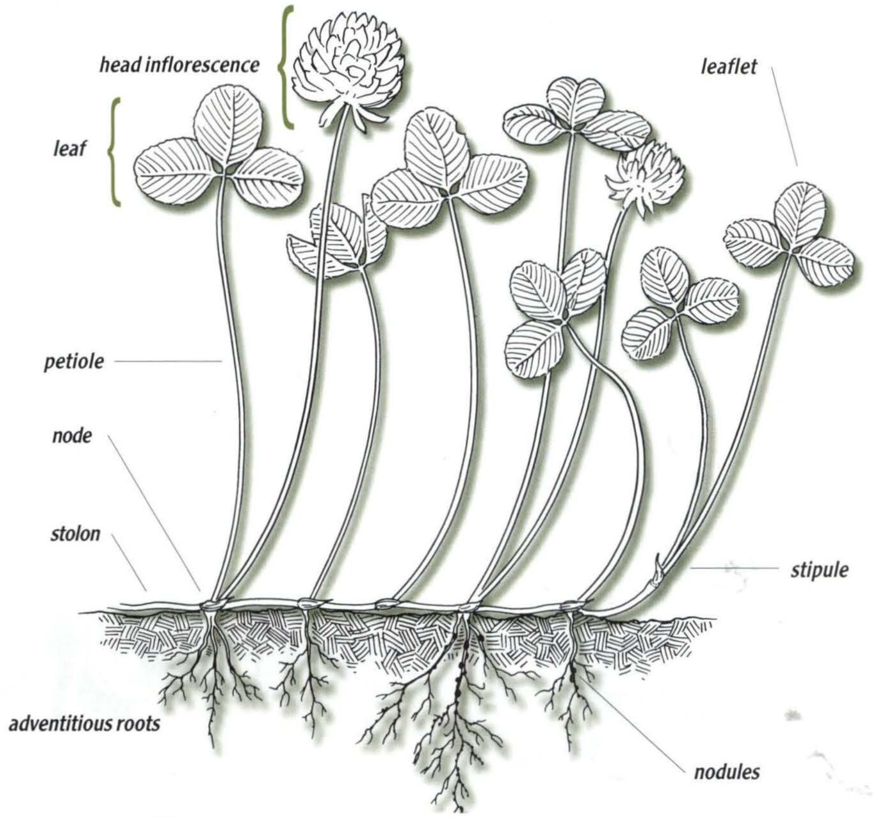
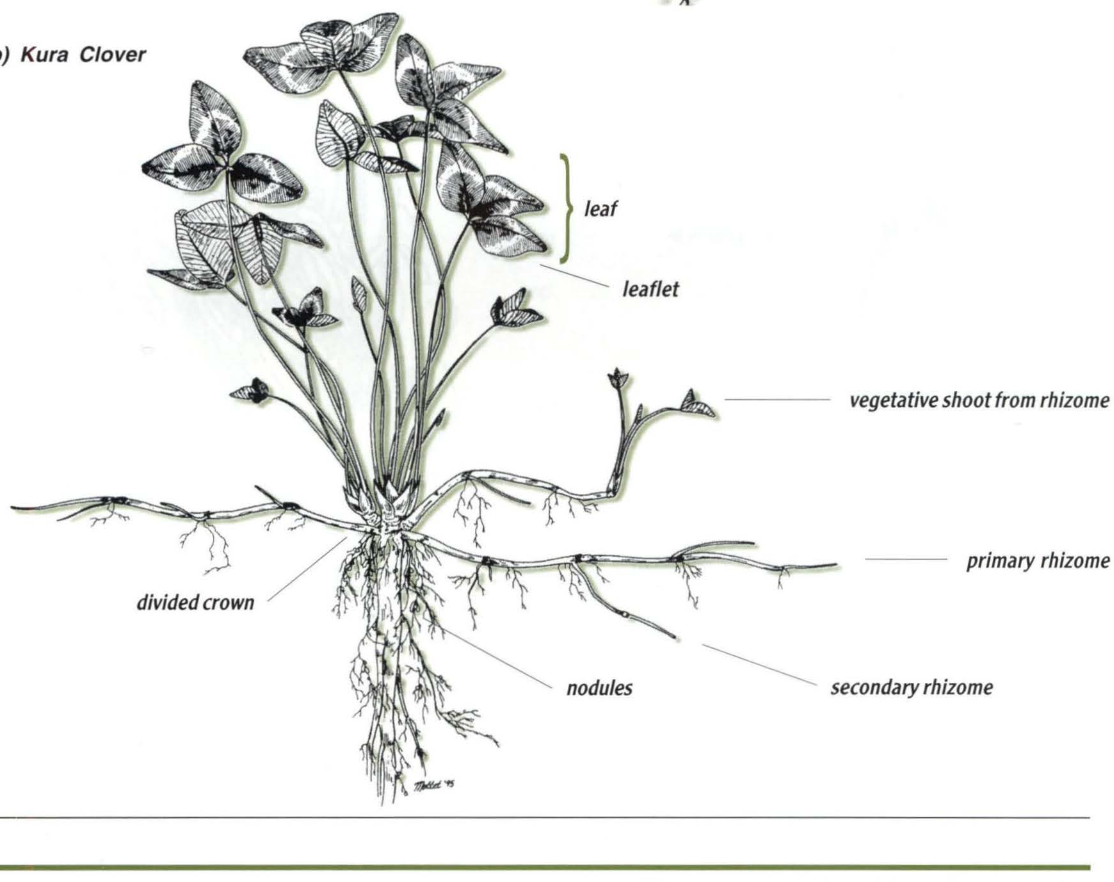


Figure E. White clover (a) stolons illustrate vegetative spreading with the development of adventitious rooting from nodes in contact with soil. Kura clover (b) spreads vegetatively with rhizomes.

(a) White Clover

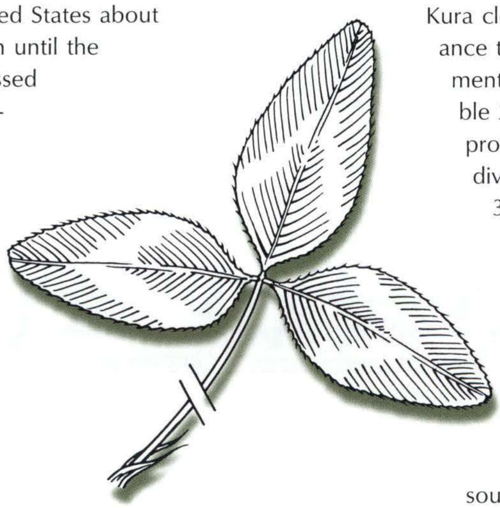


(b) Kura Clover



KURA CLOVER

Kura clover (*Trifolium ambiguum Bieb.*) is a relatively low growing, spreading perennial with excellent potential for grazing. It is also called Caucasian, Pellett's, or honey clover. It is native to the Caucasian region of Europe and named for the Kura river in the former Soviet state of Georgia. It was introduced into the United States about 1910 but remained little known until the '40s when Frank Pellett, impressed with its potential for honey production and its desirable agronomic traits, wrote about it in the American Bee Journal. However, interest did not increase until recently because of inadequate seed supplies of improved varieties and unavailability of appropriate nitrogen fixing rhizobium.



The first named United States variety, 'Rhizo', was released in 1990 by the Soil Conservation Service and the University of Kentucky. Very persistent, it has survived more than 15 years of continuous grazing at Saint Paul, Minn. and for 12 years in mixture with different grasses in Arlington, Wisc. Varieties such as 'Endura', 'Cossack' and 'NF-93', with greater seedling vigor and forage potential, are now available (table 4).

Kura clover has a deep branching taproot and has rhizomes (horizontal belowground stems) which enable it to spread vigorously (figure E). Its crowns can be two inches below the soil surface. Individual plants can increase through rhizome growth by about one foot per year with no competition; less with grass competition. By fall of the seeding year, kura clover can have significant root and rhizome growth (table 5). A five-year-old stand can produce more than three tons per acre of below-ground biomass (30 percent roots, 45 percent rhizomes, 25 percent crowns).

Leaflets are usually trifoliolate, oblong, and "water marked," with considerable variation in leaf characteristics in a population. Leaves with four or five leaflets have been observed. Leaflets and stems are not hairy, but leaflet margins are acutely serrated at the edges. Leaf size varies considerably with growing conditions during the season (1 to 3 inches long; 1/4 to 2 inches wide).

ADAPTATION

Kura clover has excellent tolerance to many stressful management and climatic factors (table 2). It has no major disease problems and is productive in diverse environments (table 3). Kura clover has greater persistence under rotational and continuous grazing, and frequent cutting, than any commonly grown legume (table 6). Following two to four cuts per year for three years in southern Minnesota, kura clover had plant populations greater than 90 percent (alfalfa and other legumes were 50 percent or less). Persistence is due in part to the extensive underground root, crown, and rhizome system that is a site for considerable carbohydrate storage. For legumes like alfalfa and red clover, root carbohydrate concentration is depleted by frequent harvesting, but concentration of carbohydrates in kura clover belowground structures is only minimally affected.

Figure F. Kura clover, birdsfoot trefoil, and alfalfa response to potassium (K_2O) fertilization.

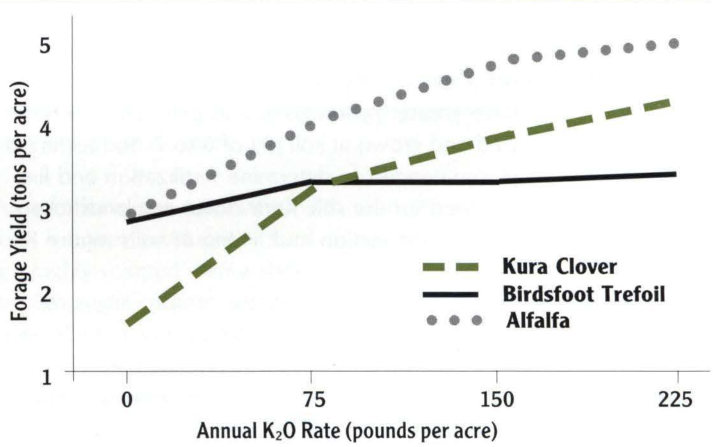
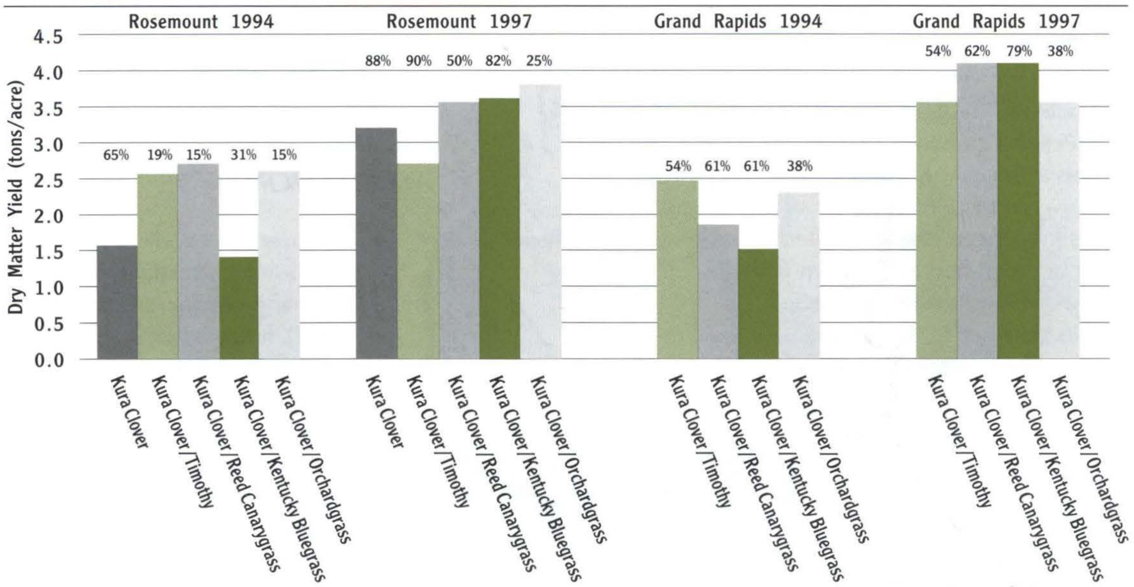


Figure G. Yields of mixtures of kura clover with perennial grasses at Rosemount and Grand Rapids, Minnesota. Percentage data above each bar is the kura clover proportion of the mixture.



Kura clover is very winter-hardy. It goes dormant in the early fall in response to short daylength and low temperatures. It is very resistant to injury due to freezing and thawing, persisting over 15 years and surviving extreme winter conditions in Minnesota and Wisconsin while all other legumes died.

Kura clover has excellent tolerance to drought, although it will become dormant during extended dry periods and yield less than alfalfa but similar to other clovers and birdsfoot trefoil (table 7). Although herbage growth is reduced during drought, kura clover resumes growth following replenishment of soil moisture. It can also often withstand poorly drained soils, survive flooding and survive on sites with a high water table. In Australia, kura clover plants had an 80 percent survival rate when flooded up to 40 days.

Kura clover is better adapted to lower fertility and pH soils than alfalfa. However, kura clover will have greater productivity and persistence if fertilized and grown at soil pH of 6 to 7. Soil testing is recommended to determine fertilization and liming need for the soil. Kura clover responds to potassium fertilization and liming of soils (figure F).

USE

Kura clover is best suited as a grazing crop because of its prostrate growth habit and very leafy, high moisture forage; however, its first growth in the spring that contains an elongated stem can be harvested for hay or haylage. Subsequent regrowth will be leaves supported by petioles originating from crowns and rhizomes. Consequently, for most of the season, kura clover is very leafy and high in feeding value (table 8). Greatest yields occur in the spring; less in summer and fall. Forage yields range from two to six tons per acre with an average of about four tons per acre most likely (tables 6 and 7).

Mixtures of grass and kura clover can be managed to produce quality forage suitable for lactating dairy cows or to support high weight gains of lambs or steers (tables 9 and 10). Kura clover tolerates rotational grazing at intervals of 14 to 28 days, or though not recommended, continuous grazing. Under stressful grazing or clipping, plants adapt by shortening leaf petioles, resulting in leaves closer to the soil surface. Unlike red clover, breeding ewes can safely graze kura clover because it does not contain phytoestrogens.

Because of very low fiber content, high protein, and potential for bloat, kura clover should be planted in mixture with perennial grasses. Mixtures should be 30 to 60 percent grass. Kura clover can be successfully established with most commonly used perennial grasses. Choice of grass species should be based on productivity and persistence of the grass at a site, and on the producer's management preference for any particular grass. Long-term grazing trials in Minnesota and Wisconsin show that grass selection influences the yield and grass composition of mixtures (figure G, table 11). Mixtures of well nodulated kura clover with grass have yielded as much as grass fertilized with up to 300 pounds of nitrogen per acre. Establishment of kura clover with the noncompetitive birdsfoot trefoil enhances seedling year and first year yields, and kura clover establishment. Over time, kura clover population increases while birdsfoot trefoil population declines.

Establishing kura clover is more challenging than for most other forage legumes. It has less seedling vigor than white clover and birdsfoot trefoil. Seedlings are fragile and develop slowly. However, resources spent establishing kura clover are an investment that provides years of returns. Forage production and stand density in the seeding year will usually be low, but it has been said, "Kura clover sleeps in the first year, creeps in the second year, and leaps in the third year."

Because of its lack of seedling vigor, it is essential to minimize competition with weeds or companion crops at establishment. Kura clover has been successfully seeded into pastures with no-till strategies, provided that existing grasses are suppressed with herbicides such as glyphosate (Cuomo et al., 2001).

Biological nitrogen fixation develops more slowly for kura clover than for other legumes. Establishment and seeding year yields can be improved by applying small amounts of nitrogen fertilizer in the seeding year on coarse soils low in nitrogen (20 pounds of nitrogen per acre at establishment, and again at first harvest approximately 60 days later). However, nitrogen fertilization can sometimes also increase weed competition if weeds are not controlled.

Because of its prostrate and spreading growth habit, kura clover has potential for use in soil stabilization projects. Its dense rhizome mat holds soil and prevents erosion. With adequate suppression and seeding technology, kura clover can also be managed as a living mulch in corn with little or no reduction in grain or silage yield (Zemenchik et al., 2000; Affeldt et al., 2000) (table 12). Kura clover supplies almost all the nitrogen required, provides permanent ground cover to reduce soil and nutrient run-off, and recovers to full production of pasture the following season.

SEED PRODUCTION

Kura clover flowers in response to long-days in the spring. Initial regrowth is upright stems supporting one or two large, fragrant, pink-white flowers. If the initial regrowth is not cut and allowed to mature, seed is produced in July or August. Producing kura clover seed is more difficult than for many other legume forage species. The grower should consider a field's previous crop history. Seed purity is an issue because legumes previously on the site, such as red clover, produce seed of similar size to kura that is difficult to separate.

Seed production fields are seeded in rows, or broadcast, at approximately one-quarter of the forage seeding rate. A firm seed-bed allowing a uniform seeding depth of ¼- to ½-inch is desirable. Kura clover is generally established using herbicides, without a companion crop, after the initial spring weed flush, and before late July. Soil fertility requirements for seed production are the same as for forage production; a soil test prior to establishment and every two years during production is recommended. After establishment, roguing or spot spraying to eliminate problem perennial weeds such as thistles may be necessary.

Pollinating insects, especially bees, are important for seed production. One honeybee hive per acre is recommended for seed production, but more bees may be required if there is competition for pollinators from other crops.

Successful harvesting requires prompt, timely and careful action. Fields may be swathed when the majority of the stems have turned brown, and combined after drying, or it may be direct combined in the field after use of a chemical desiccant. To maximize seed yield, careful combine calibration is required because the seed is difficult to thresh. Kura clover seed fields may become sod bound after several years due to the large root mass and rhizome production. Decline in seed production may follow, necessitating taking the field out of production.

An additional use associated with seed production, is honey production. Kura clover flowers are highly scented with a shallow corolla, keeping its high sugar content nectar readily available to bees. Kura clover pastures or seed production fields can be managed to produce honey as an additional source of income if kura clover is allowed to flower.

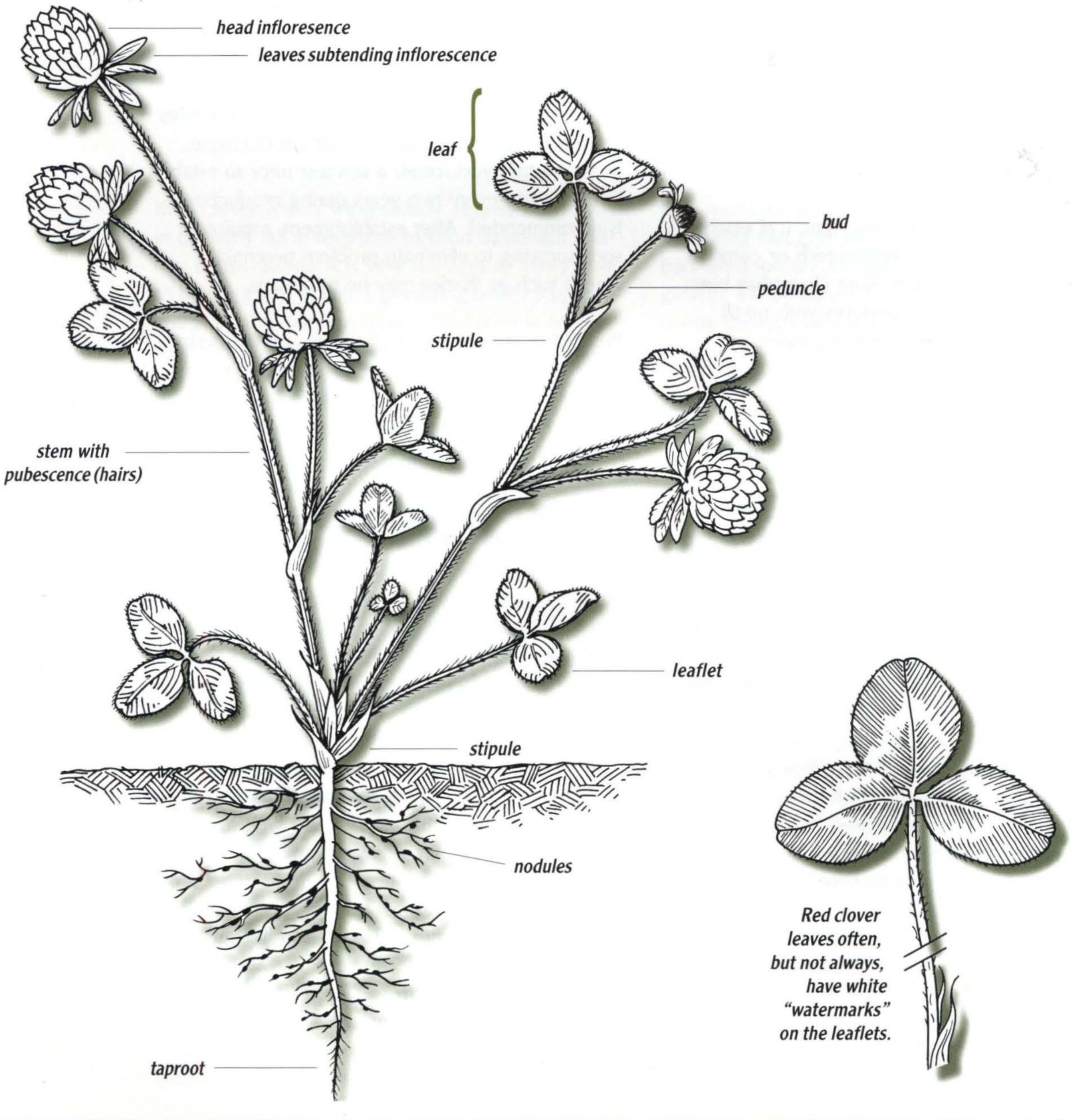
RED CLOVER

Red clover (*Trifolium pratense* L.) is native to Asia and southern Europe and is the most important and widely distributed of the clovers. Its name is likely derived from the deep red color of its blossom.

Red clover was introduced into England in 1650 and apparently into North America shortly afterwards by the early colonists (Piper, 1924). It is sown on more acres than any other clover, and grown both alone and in grass mixtures.

There are two general types of red clover. Most of the varieties grown in the northern regions of the United States are 'medium' or multiple cut types. The other type, mammoth red clover, is later flow-

Figure H. Red clover plant illustrating upright growth habit.



ering than medium red clover and produces only one crop of hay per season. Mammoth red clover is best adapted to the more extreme growing conditions in northern Minnesota.

Red clover has pubescent (hairy) upright growing stems that originate from a narrow crown near the soil surface (figure H). The plant has a tap root with many side branches, but its roots do not penetrate the soil to the depth of sweetclover and alfalfa.

ADAPTATION

Red clover is a short-lived perennial which usually persists only two or three years. Breeders have improved its resistance to diseases and have improved the persistence of many red clover varieties. Marathon is an example of an improved variety. (See *Minnesota Varietal Trials Results,* annual information published on the web at www.maes.umn.edu by the Minnesota Agricultural Experiment Station, and in a print edition with the cooperation of the Minnesota Crop Improvement Association).

Red clover is adapted to a wide range of soil types except those in areas prone to drought. It tolerates a pH as low as 5.5.

Red clover's persistence is reduced by high temperature, low moisture, and flooding. Red clover is susceptible to winter injury partially because the crown of the plant is at the soil surface and is not beneath it like alfalfa and kura clover crowns. In areas without adequate snow cover, red clover may only live one year.

USE

Red clover is used for hay, silage, and pasture. It is often used as a hay and pasture crop alternative to alfalfa on heavy soils of low pH in northern Minnesota (tables 13, 14 and 15). In southern Minnesota, it generally yields less and is less persistent than alfalfa, partly due to its low drought tolerance (tables 2, 6, 7 and 24).

Red clover produces high quality forage due to leafiness and stems which are relatively high in nutritive value (tables 7, 19 and 21). It also has somewhat greater undegradable protein and greater stem and fiber digestibilities than alfalfa. Red clover has enzymes that result in less protein breakdown to non-protein nitrogen during ensiling.

Animal performance on red clover pasture is similar to their performance on alfalfa (tables 9, 19 and 21). However, the long term carrying capacity and production per acre is lower for red clover than for alfalfa due to less stand persistence.

Red clover is a two- or three-cut crop that is usually harvested at early flowering (when about 25 percent of the stems are flowering). Allowing the crop to reach full flower (with 100 percent of the stems having mature flowers) will result in low quality forage. Because red clover is high in moisture, it is also sometimes difficult to dry it to moisture levels low enough for storage as hay. Low moisture silage is often made to reduce risk of rain damage.

Red clover is frequently planted in mixtures with grasses to minimize the incidence of ruminant bloat during grazing and to enhance hay drying. Red clover hay may cause slobbering by livestock if the hay becomes infected by black patch disease. This disease is caused by *Rhizoctonia leguminicola,* which produces the alkaloid slaframine, which induces salivation (Taylor, 1985). Red clover contains phytoestrogens that reduce conception rates of ewes that have consumed red clover pasture or silage.

Red clover has excellent seedling vigor and is good for pasture renovation using sod-seeding or frost-seeding (table 17).

Red clover also offers potential for on-farm seed production. For multiple cut varieties, the first crop in early June is harvested or clipped and seed is produced on the second crop. Seed yields are dramatically increased if adequate pollinators such as honey bees are present. For more information on red clover seed production see *Red Clover in Minnesota* (Justin et al., 1967).

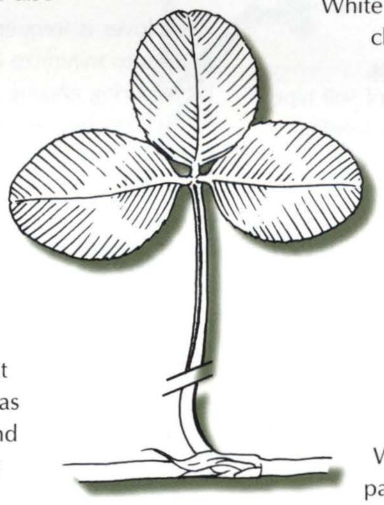
WHITE CLOVER

White clover (*Trifolium repens* L.) is distributed throughout the world. It thrives in areas with fertile soils, good soil moisture, and grazing animals. Its exact origin is disputed, but it most likely evolved either in the eastern Mediterranean region or in western Asia.

White clover was grown in England in the early 1700s and was introduced into North America by early colonists. As land was cleared for farms and deforestation occurred in the colonies, the small seed of white clover was rapidly spread by grazing livestock and other animals.

White clover is not a major cultivated forage legume in the north central region of the United States, because it generally has poor persistence and low productivity (tables 6, 14, 15 and 16). However, because of its prolific seed production it is widely distributed and found in lawns, pastures, and waste areas. It is also frequently included as a component of pasture mixtures.

As its name implies, white clover has white blossoms borne on long peduncles. White clover is unique among legumes because it spreads by stolons (horizontal above-ground stems) (figure E). It's herbage is usually shorter than that of other legumes because it has no upright stems. Its leaves and flowers originate from stolons on the soil surface.



Three types of white clover grow in the north central region of the United States. These are ladino, white Dutch (also known as intermediate or medium) and wild white clover. White Dutch and wild white clovers are very prostrate. They are often found in permanent pastures and lawns. They flower profusely and reseed themselves. Although they have low forage productivity, these clovers contribute nitrogen for use by grasses in pastures.

Ladino white clover is a large type of white clover which is more productive than the Dutch or wild white clovers and is suited for forage production. Most white clovers sold in the United States are unnamed common types because little variety development has occurred. 'Merit 3', 'Shasta' and 'Sacramento' are older varieties that are sometimes available. Recently, the varieties 'Alice' and 'Kopu II' were developed in New Zealand for use in grazing systems, and 'Kopu II' has demonstrated superior stolon density and survival over a three year period in Wisconsin (table 18).

ADAPTATION

White clover is adapted to soils and regions which have a constant supply of moisture. It has a very shallow root system and no drought tolerance. White clover is most productive during summers with cooler temperatures and well distributed rainfall. It tolerates acid soils (pH 5.5) but not saline or alkaline soils.

White clovers are less winter-hardy than red clover and though they can overwinter, plants will not usually survive without adequate snow cover. White clover primarily persists in pastures by regeneration from seed produced the previous year although stolons can sometimes overwinter. Persistence is also reduced by numerous diseases.

USE

White clovers are most often used for pastures, and are often sold as components of pasture mixtures which include grasses. Recently, ladino white clover has been included as a component in wildlife mixtures being sold to feed and attract whitetail deer. White Dutch and wild white clovers often naturally occur in heavily grazed pastures and regenerate each year by reseeding. White clovers are good for frost seeding into pastures in winter or early spring.

White clovers have high forage nutritive value (table 19) because the forage consists mostly of leaves, but the forage can cause bloat. Ladino clover is the only white clover which grows tall enough to be cut for hay. Harvesting at early flowering is recommended.

BIRDSFOOT TREFOIL

Birdsfoot trefoil (*Lotus corniculatus* L.) is a native of Europe and Asia. It may have been brought to the American colonies in soil used for ship ballast. Plantings were established in the late 1880s at several agricultural experiment stations in the eastern United States. It is frequently used as a ground cover and its bright yellow flowers are often seen along highways during the spring and summer.

Birdsfoot trefoil derives its name from the claw-like arrangement of its seed pods, which to some resembles a bird's foot. The pods shatter and release their seeds when ripe, making seed harvest difficult.

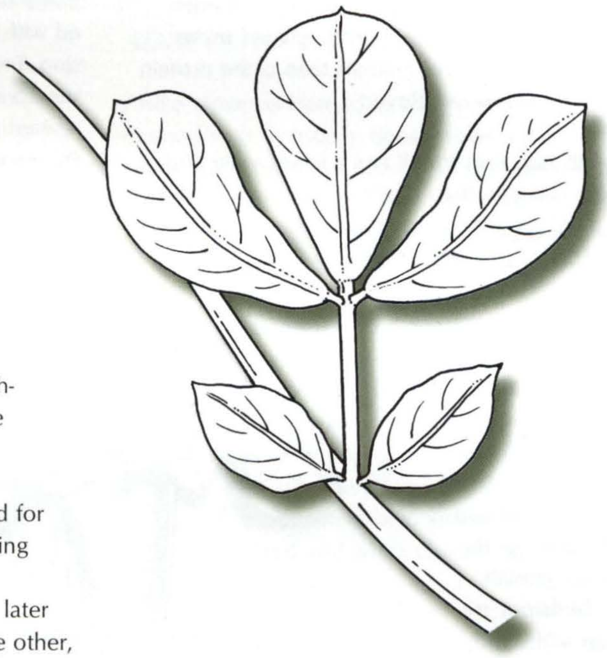
Birdsfoot trefoil has fine stems which tend to lodge. It makes considerable regrowth from axillary buds on its lodged stems and is less dependent on regrowth from crown buds than is alfalfa. Its leaves consist of five leaflets, three grouped together at the end of the petiolule and two at the leaf base.

Two main types of birdsfoot trefoil are used for forage production in Minnesota. Low growing types such as 'Empire' and 'Dawn' are fine stemmed and very prostrate. Both are also later in flowering and more winter-hardy than the other, upright (also called European) types. 'Viking' is an upright type.

Low growing types of birdsfoot trefoil are best suited for pasture. The upright types are adapted to both hay and pasture usage. They make more rapid regrowth but are less persistent than the low growing types. 'Norcen' is an intermediate type which is persistent and well adapted to growing conditions common in Minnesota.

Two new varieties of birdsfoot trefoil, 'Neultin' and 'Roseau', have been released by the Minnesota Agricultural Experiment Station. Both are broad-leaved cultivars. 'Neultin' has good spring vigor and excellent winter hardiness. It is similar in forage yield potential to 'Norcen' and should be widely adapted to northern areas of the United States and adjacent areas of Canada. 'Roseau' has an intermediate growth habit and is adapted to a wide range of environmental conditions. It is similar in forage yield potential to other currently available cultivars, and is less winter-hardy than 'Neultin' though more hardy than 'Empire'.

Birdsfoot trefoil has very small seeds and poor seedling vigor. Care must be taken to assure its establishment.



ADAPTATION

Birdsfoot trefoil is very tolerant of waterlogged soils and can withstand several weeks of flooding. It is also tolerant of acid soils (pH 5.0), and is moderately tolerant of high alkalinity and salinity. On acid and poorly drained soils, birdsfoot trefoil will have greater yields than red clover and alfalfa (table 20).

Birdsfoot trefoil is adapted to most areas of Minnesota but has only moderate drought and heat tolerance. It is less winter-hardy than alfalfa. Although birdsfoot trefoil is a perennial, when it is intensively managed, forage yield and stands will usually persist for only three or four years due to disease and winter injury. Its yield and persistence are best when cut or grazed two to three times per season.

Stand persistence can be achieved by allowing the crop to flower and set seed. Pods shatter when mature, and seeds are dispersed by wind, water or grazing animals.

USE

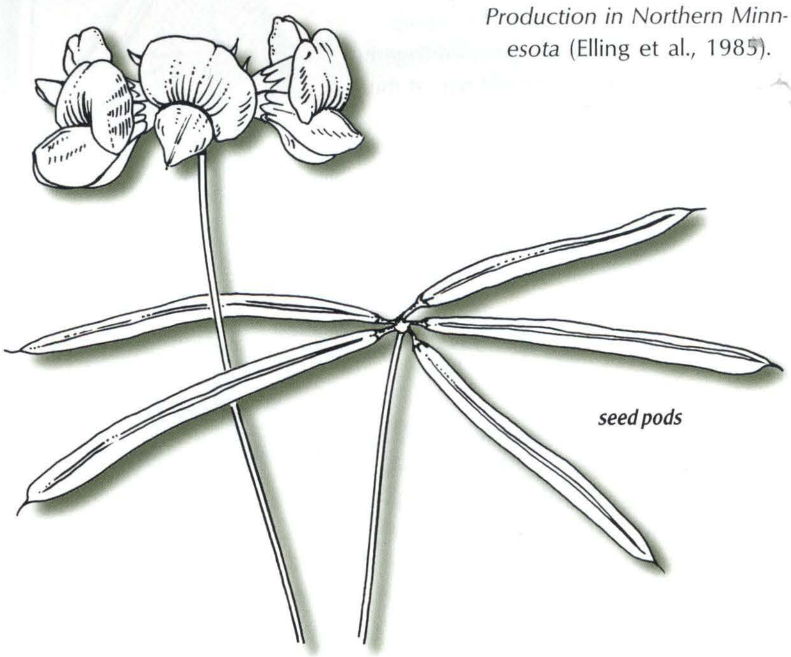
Birdsfoot trefoil should be considered primarily for pasture systems where animals can graze the forage. Birdsfoot trefoil contains tannins which prevent legume bloat in grazing animals. In addition, because the protein in birdsfoot trefoil is less readily broken down by microbes in the rumen ("bypass protein"), its protein is utilized more effectively by ruminant animals than is the protein in either alfalfa or red clover.

Although birdsfoot trefoil has a lower yield and carrying capacity than alfalfa, it can provide high daily gains for grazing animals (tables 6, 15, 16, 21 and 22). Birdsfoot trefoil is a good legume to accumulate in place (stockpiling), delaying grazing until midsummer or late fall following a killing frost, when forage is usually in short supply. Because of its prostrate growth habit, birdsfoot trefoil can withstand heavy grazing.

Delayed grazing is possible with birdsfoot trefoil because it holds its leaves at maturity, retaining its forage quality. Delayed grazing will also allow abundant seed production and natural reseeding. This makes birdsfoot trefoil pasture a good component of a grazing system which uses cool season grasses or other forages for early spring grazing, leaving birdsfoot trefoil grazing for the middle part of summer.

Birdsfoot trefoil is difficult to cut for hay because of lodging, but it can produce a high quality hay crop (tables 7, 19 and 20). Hay harvests should occur at early flowering. Mechanical harvesting for hay or silage will generally reduce stand life compared to grazing. Birdsfoot trefoil should be seeded with a grass like timothy to reduce weed invasion. For performance of birdsfoot trefoil varieties, see *Minnesota Varietal Trials Results,* an annually revised publication of the Minnesota Agricultural Experiment Station.

Birdsfoot trefoil is a prolific seed producer and in northern Minnesota a seed industry has been established. For information on seed production see *Birdsfoot Trefoil Production in Northern Minnesota* (Elling et al., 1985).



ALSIKE CLOVER

Alsike clover (*Trifolium hybridum* L.) is named after a location in Sweden where it was cultivated as early as 1750 (Piper, 1924). It is a distinct species, not a hybrid of red and white clover as was once thought. Alsike clover is native to the temperate regions of Europe and Asia. Seed was distributed in the United States by the Patent Office in 1854 but was probably introduced into the United States about 1839 (Townsend, 1985).

Although alsike clover was once frequently used on poorly drained and acidic soils, when all forages were only infrequently harvested, it is not currently a prominent forage legume. Alsike clover is still used as a component of hay and pasture mixtures, with red clover and grasses such as timothy and red top, because of its low seed cost and adaptation to specific soil conditions.

Alsike clover volunteers in many permanent pastures and roadsides in areas of the region with adequate rainfall and good winter snow cover. It can be perennial under such ideal conditions, but in the north central region it typically behaves as an annual or biennial. There are no released varieties specifically developed in the United States; most seed is common. 'Tetra' is a tetraploid variety developed in Sweden, and in Minnesota has similar yield and persistence as the common varieties.

Alsike clover has an an upright growth habit like red clover, but because its stems are fine they usually lodge if alsike is not grown in mixture with a more upright grass or legume. Alsike clover stems can grow three to five feet long if uncut, though stems are normally one to two feet in length. Its leaves and stems lack pubescence. Leaflets are finely serrated along the entire edge and are never varigated or "watermarked."

Alsike clover has white to pinkish flowers that originate in leaf axils up and down the stem. The flowers are similar in size to those of white clover.

Alsike clover has an indeterminate growth habit that results in uncut stems potentially bearing buds, flowers, immature seeds and ripe seeds simultaneously along its entire length. Seeds originating on flowers from lower portions of the stem may shatter before blooming on upper portions of the stem ceases. Therefore, on adapted soils, there is usually a large supply of hard seed produced to contribute to natural reseeding in later years.

ADAPTATION

Alsike clover is best adapted to moist or poorly drained soils. It usually does not persist on dry sandy soils and is not tolerant of drought or high temperatures. It will tolerate waterlogged soils and can withstand spring flooding for up to six weeks. Alsike clover will tolerate acidic soils with a pH of 5.0. Alsike clover is best adapted to the cool, moist climate of the northern parts of the north central region of the United States, and to low lying moist areas in the southern part of the region. It can persist and be relatively productive on wet soils, acid and alkaline, where red and white clovers do poorly.

USE

Alsike clover is used for hay and pasture but its forage yield and persistence is low relative to other legumes, especially when grown on upland fertile soils and cut frequently (tables 6, 14, 15 and 16). It is best adapted to mixtures with grasses like timothy that are infrequently harvested, and are harvested at full bloom.

For hay production, usually only one or two cuts are possible. First spring growth that occurs under cooler conditions usually represents about 80 percent of the total season yield. Likewise, under grazing, greatest yields should be expected in the spring, with little yield during summer grazing. Forage is often of higher quality and leafier than forage of red or white clover (table 19). Alsike clover can cause bloat and photosensitization.

SWEETCLOVER

Sweetclover is native to the Bakhara region of Asiatic Russia. It has been used as a green manure and a honey plant for more than 2,000 years, and was first reported growing in North America in Virginia in 1739. It was later recognized for its soil reclamation properties, beginning around 1900, when it was successfully grown on many depleted and eroded soils of the southern United States (Smith and Gorz, 1965).

Acreage planted to sweetclover has declined from its peak of use in the decades between 1925 and 1950. Its decline came about as the result of several factors. These included a decrease in the use of rotations, the prevalence of cheap synthetic fertilizers, a potential danger to ruminants from bleeding disease, and damage by the sweetclover weevil (*Sitona cylindricollis* Fahr).

The sweetclover weevil is a dark green snout beetle about 3/16-inch long. Adult weevils consume new seedlings and eat crescent shaped areas from young leaves. Larvae injure the plant by attacking roots.

A limited amount of sweetclover is grown on government conservation program (CRP) acreage. Sweetclover is also commonly found on wasteland and on roadsides, where it regenerates by self seeding. Wheeler (1950) indicated that, "sweetclover will grow anywhere, provided there is more than 17 inches of well distributed rain, and the soil is not sour."

All sweetclovers contain coumarin, a bitter, stinging tasting substance with a vanilla-like odor. Coumarin is indirectly responsible for bleeding disease in livestock. In spoiled and molded sweetclover hay, coumarin is transformed to dicoumarol. Dicoumarol is an anticoagulant, and cattle and sheep consuming spoiled hay develop bleeding disease. Horses seldom develop bleeding disease, but can develop colic from moldy hay. 'Denta' is a low coumarin variety developed in Wisconsin. Other low coumarin varieties are now also being marketed.

Although a cause of death in livestock, dicoumarol and its derivatives have saved many human lives by reducing blood clotting after surgery and by reducing the incidence of coronary thrombosis. Derivatives of dicoumarol are also used in products like Warfarin for rodent control.

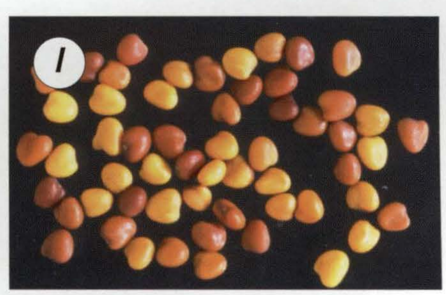
Most sweetclover varieties, being biennial, flower and die after their second year. There are white and yellow flowered types of sweetclover. Yellow sweetclover (*Melilotus officinalis* L.) flowers about two weeks earlier than white. The yellow types are smaller and lower yielding, but also leafier and more drought tolerant than white sweetclover (*Melilotus alba* L.).

In terms of biomass production, yellow and white varieties are similar. Yellow sweetclover makes less top growth in the fall of the first year than do white varieties, but yellow increases its biomass yield with greater root growth. White sweetclover (also known as Bakhara, or Bakhara melliot) is taller and has a coarser stem than yellow sweetclover. Most seed sold is common, however 'Evergreen' (white blossomed) and 'Madrid' (yellow blossomed) are two old named varieties that are sometimes available.

'Hubam' is an annual white blossomed sweetclover variety. It is used as a green manure and emer-

Seeds of Nine Legumes — Images are magnified approximately three times actual size and are sized accurately RELATIVE *to each other; actual colors may vary with variety and seed lot.*

A = alfalfa	*F = kura clover*
B = alsike clover	*G = red clover*
C = birdsfoot trefoil	*H = sweetclover*
D = cicer milkvetch	*I = white clover*
E = crownvetch	



Alsike Clover

Alfalfa

Birdsfoot Trefoil

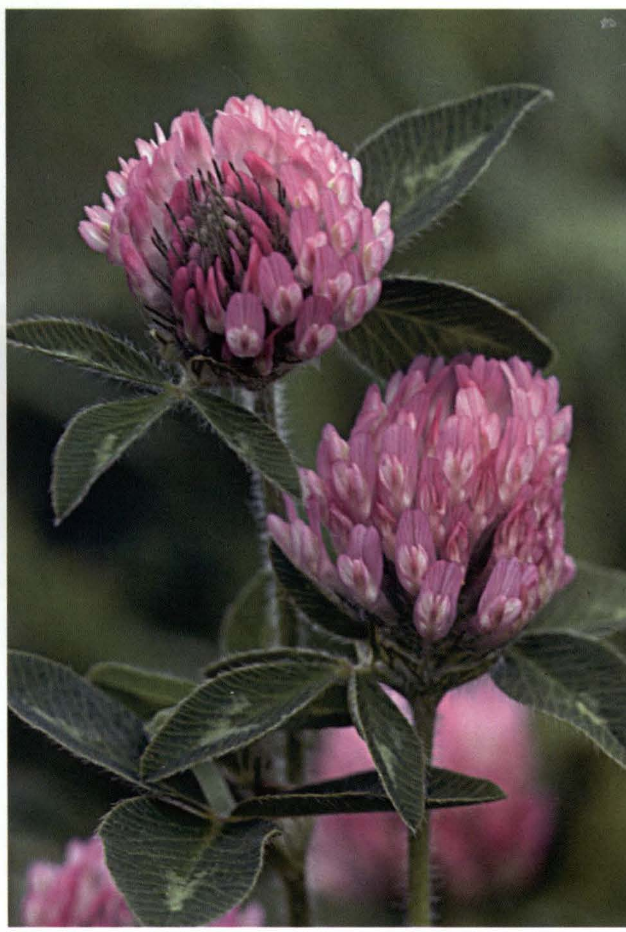
Crownvetch

Cicer Milkvetch

Kura Clover

White Clover

White and Yellow Sweetclover



Red Clover

gency hay crop. It yields more forage but produces less root than the biennial sweetclovers.

Sweetclover leaves are pinnately compound with serrations around the entire leaf edge.

Sweetclovers plants are tall. They grow to heights of two to four feet, and have a thick, coarse stem. They produce large quantities of seed.

ADAPTATION

Sweetclover requires nonacid soils (pH greater than 6.5) that are reasonably well drained. It is the legume best adapted to highly alkaline soils. It is intolerant of poorly drained and flooded soils, but is drought resistant and winter-hardy.

USE

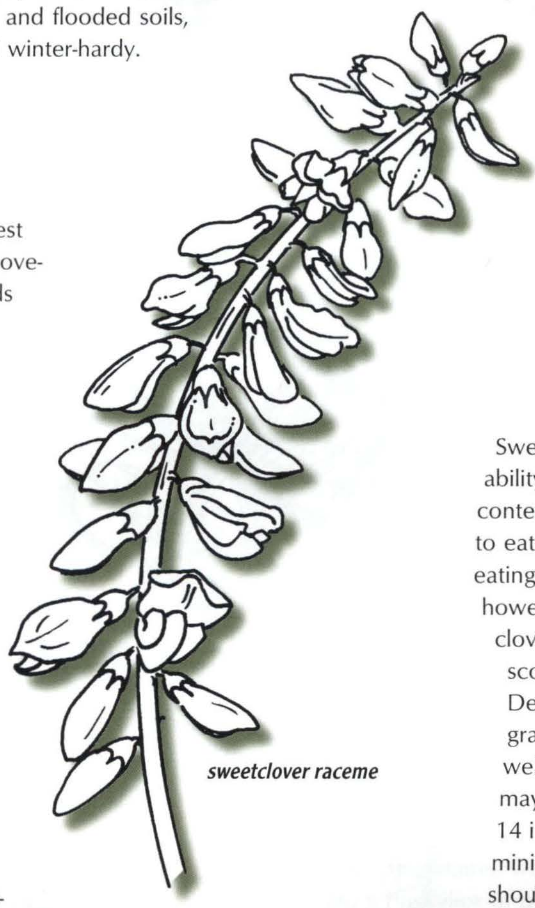
Sweetclover is one of the best legumes for use in soil improvement. It produces high yields of both herbage and root nitrogen, as well as organic matter when not cut (table 23). Before the advent of synthetic fertilizers, sweetclover was routinely used as a green manure crop in the Corn Belt.

When grown for green manure, biennial sweetclover is plowed under in the spring of the second year. Plowing in the spring will kill the plants, provided plant growth is at least three inches. In contrast, with fall plowing, plants can regrow in the spring and become a weed control problem.

Sweetclover is also an excellent source of high quality honey. It produces an abundance of nectar and the honey derived from it is light colored and mild flavored. One acre of sweetclover is sufficient for one hive of bees.

Sweetclover is not a preferred legume for harvested forage. It is tall growing and stemmy, and the forage tends to be low in quality, but when cut for hay, yields of two to four tons per acre can be achieved.

The best stage at which to cut sweetclover for hay is at bud to early blossom. A stubble of eight to 12 inches is usually left to encourage regrowth because regrowth comes from axillary buds on the stem instead of the crown. Any cutting of biennial sweetclover the first year reduces root size and vigor the second year. Because of its high moisture content and its rank growth, curing is difficult.



sweetclover raceme

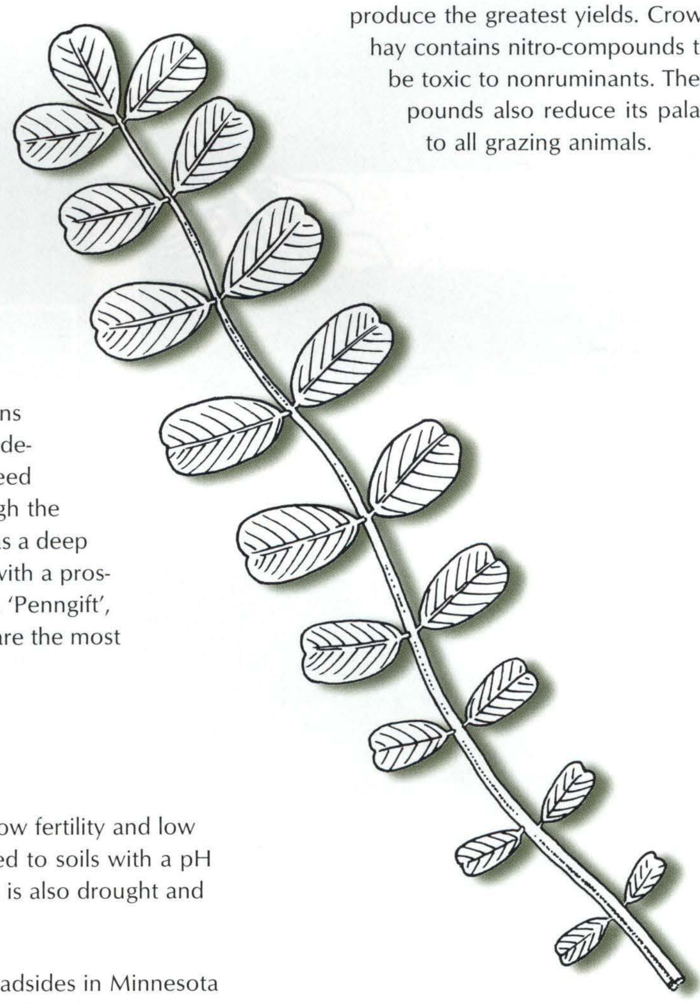
Sweetclover is low in palatability because of its coumarin content, and animals will tend to eat other vegetation before eating sweetclover. Animals can, however, adjust to it. Sweetclover also will cause bloat, scouring, and may taint milk. Despite these limitations, grazing animals can perform well on sweetclover. Grazing may begin when plants are 14 inches in height, but a minimum height of eight inches should be maintained to allow rapid regrowth. Plants become woody and unproductive if allowed to reach bud stage before initiating grazing.

CROWNVETCH

Crownvetch (*Coronilla varia* L.) is a native of middle and southern Europe. It was commercially available in the United States as an ornamental as early as 1890. Interest in crownvetch use as a forage was generated by its discovery in a field in Pennsylvania in 1935; it had been started from plants originally sown about 30 years earlier. The variety 'Penngift' was derived from that population (Musser et al., 1954).

Crownvetch has been extensively used for roadside stabilization and land reclamation, and for ornamental purposes. It has not developed into an important forage legume in the north central region of the United States.

Crownvetch derives its name from its vetch-like leaves and the crown-like arrangement of its white-purple flowers in its inflorescence. Seeds are borne in non-shattering pods that break into sections when dry. Crownvetch is indeterminant. Flowering and seed production continue through the entire growing season. It has a deep and creeping root system with a prostrate herbage growth habit. 'Penngift', 'Emerald', and 'Chemung' are the most widely used varieties.



ADAPTATION

Crownvetch is tolerant of low fertility and low pH soils, but is best adapted to soils with a pH of 6 or above. Crownvetch is also drought and disease tolerant.

Crownvetch survives on roadsides in Minnesota where it is not mowed and where it is protected from low winter temperatures. However, crownvetch should not be considered for forage use in Minnesota because it lacks winter hardiness and has poor persistence when harvested (tables 6, 15 and 16). Crownvetch has very poor seedling vigor and may require two years for successful establishment. Stands have also been established by planting excised crowns which are available in many nurseries.

USE

Crownvetch is best adapted for non-agricultural uses. However, if crownvetch is used as a forage, it is best adapted for pasture because of its prostrate growth habit and non-bloating characteristic. If harvested for hay, two harvests per season produce the greatest yields. Crownvetch hay contains nitro-compounds that can be toxic to nonruminants. These compounds also reduce its palatability to all grazing animals.

CICER MILKVETCH

Cicer milkvetch (*Astragalus cicver* L.) has been evaluated and used for forage in the Great Plains and western United States. It has, however, only been evaluated in a limited number of trials in Minnesota.

Cicer milkvetch is a vigorous, persistent, high yielding legume which spreads by rhizomes and has a deep root system (tables 6, 15, 16 and 19). Stands of cicer milkvetch have persisted ten years under stressful conditions in Minnesota.

The herbage of cicer milkvetch is upright during regrowth, but because its stems can reach a length of four feet, they will lodge with maturity. Its leaves are pinnately compound with eight to 17 pairs of leaflets and a single terminal leaflet. Yellow to white flowers are borne on racemes that originate in leaf axils. Its seed pods are bladderlike and can contain as many as 12 seeds.

Cicer milkvetch has low seedling vigor and may take two years for good establishment. 'Lutana' and 'Monarch' are two varieties released in the United States.

'HiPal' cicer milkvetch, which was selected for improved palatability using grazing sheep, has been released by the Minnesota Agricultural Experiment Station. It is more palatable than earlier varieties, with sheep consuming 53 percent more of the available forage after grazing for six to nine days. At the end of such grazing periods, 'HiPal' represented 89 percent of the forage that was consumed by the grazing sheep. This compared to only 68 percent of the consumed forage being cicer milkvetch for pastures seeded with the older 'Monarch' and 'Lutana' varieties. 'HiPal' generally has similar forage quality but higher crude protein concentrations than those older varieties.

ADAPTATION

Cicer milkvetch tolerates soil with slight acidity to moderate alkalinity. It is intolerant of wet soils or flooding. Forage yield is reduced by drought but stand persistence is not affected (table 24). Cicer milkvetch is very winter-hardy and disease and insect resistant.

USE

Cicer milkvetch has potential as a harvested or grazed forage crop. When harvested for hay, the recommended stage of development is flowering. But, because of slow regrowth it is only a two- or three-cut crop when cut at the flowering stage. Forage nutritive value is high, often exceeding that of alfalfa.

Cicer milkvetch has a high carrying capacity when grazed, but sometimes provides lower average daily gains for livestock than do most other legumes (tables 21 and 22). This is due to unknown antiquality constituents which reduce palatability (it is not eaten by livestock when a choice is given) and cause photosensitization and hair loss by grazing ruminants. Use of the more recently released variety 'HiPal' reduces these problems, though additional evaluation is required before widespread use of cicer milkvetch for grazing can be recommended.

ALFALFA

Alfalfa (*Medicago sativa* L.) is the most important and most widely planted perennial forage legume grown in the north central region and across the United States. It is, therefore, the legume against which all others are measured. Alfalfa is included in this publication primarily for the purpose of comparison.

Production of alfalfa for forage predominantly occurs in the north central states of Minnesota, Wisconsin, North Dakota and South Dakota. However, seed is primarily produced in California, Idaho, Washington, Nevada and Oregon, where the climate and pollinators are optimum for good seed yields.

Alfalfa originated in southwestern Asia near the vicinity of modern day Iraq, Iran, and Afghanistan. It was described as a source of animal feed as early as 490 before the common era, by the Roman writers Pliny and Strabo. It has been dispersed throughout the world by explorers, armies, and colonists.

alfalfa leaflets are serrated on about one-third of their edge

Alfalfa is believed to have been originally introduced into the eastern North American colonies in 1736, with several additional early germplasm introductions occurring between 1840 and 1900. Especially notable for northern states, such as Minnesota, was the introduction of a north central region winter-hardy variety in 1858 by Wendelin Grimm, an immigrant from Germany. Named for him, the variety 'Grimm' was selected from his initial seeding in Carver County, Minnesota.

There has been considerable successful breeding of alfalfa varieties by public institutions such as land grant universities, and by private companies. This has produced many persistent, pest resistant and high yielding alfalfa varieties. Currently, more than 100 alfalfa varieties are marketed in Minnesota (See *Minnesota Varietal Trials Results*).

Most commercial alfalfa varieties have a deep tap root and upright herbage which originates from a large crown. Its leaflets are serrated along one-half to one-third of the leaf margin. Flowers are typically purple, but on some varieties may be yellow, white, cream, or varigated across shades of blue and green.

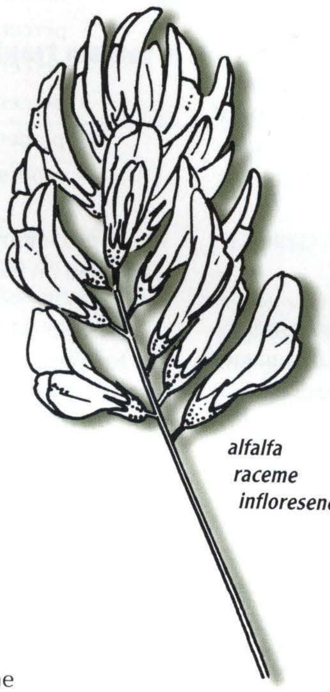
Rooting depths of 20 to 30 feet are frequently reported for alfalfa. Herbage can reach a height of three to four feet if not cut. The crop will, however, usually lodge before reaching that height. A few alfalfa varieties have creeping roots and rhizomes which result in a more prostrate growth habit.

ADAPTATION

Alfalfa requires soil pH of 6.5-7.0 and high levels of soil nutrients for good persistence and yield (table 2). Potassium is especially critical for high yields and persistence. Alfalfa is intolerant of flooding and water logged soils.

Persistence of alfalfa and other perennials is frequently affected by winter injury. The extent of winter injury is determined by plant and environmental factors. During the winter, the alfalfa plant is somewhat like a hibernating bear. The plant has a low level of metabolic activity, and it relies on stored carbohydrate reserves for energy during the winter and for regrowth in the spring. Perennial portions of the plant, its crowns and roots, are dormant in the winter, and in the spring the plant regrows from crown buds formed the previous fall. Cold tolerance is greatest for crown buds and least for the roots.

Decreasing fall temperatures, and shortening day lengths, cause biochemical and morphological changes that allow the plant to tolerate low winter temperatures. While temperatures below 25°F can kill alfalfa during the summer; during the fall, very dormant and winter-hardy varieties can withstand temperatures as low as -5°F. However, most commonly grown hay varieties will experience winter injury at soil temperatures below 5°F. Prolonged seven to ten day exposure to temperatures above about 45°F can cause alfalfa to break dormancy and become susceptible to freezing injury. Dormancy is most easily broken by these temperature levels in late winter and early spring.



alfalfa raceme infloresence

Alfalfa and other perennial plants are protected from freezing winter temperatures by the soil, plant residue and snow. First line of defense for the plant is to have a crown deeply buried by the soil. Varieties vary in this trait and winter-hardy, grazing tolerant types often have the deepest crowns. Plant residue, such as dried stems and leaves, protects the soil from rapid freezing and from freezing and thawing, and catch snow that insulates the soil from low temperatures. A minimum snow depth of about five inches is needed to insulate the soil.

USE

Alfalfa is used for hay, silage and pasture. In the north central region of the United States, small quantities are also dehydrated. Fields are often used for both grazing and hay production. Because alfalfa's forage quality potential is high (table 19), it is often a key component of ruminant rations. Under good growing conditions, alfalfa produces greater yields of forage dry matter and protein per acre than any of the other commonly grown forage legumes (tables 6, 15 and 16).

Regional and local growing conditions, as well as the goals of the producer, all influence optimum harvest management decisions. Producer goals are usually based on the relative value of forage yield, forage quality, and stand persistence in specific systems. For example, a dairy producer in southern Minnesota who routinely four-cuts alfalfa at bud stage, sacrifices dry matter or nutrient yield and stand persistence for excellent quality forage. Such a forage has value as feed and replacement for high-cost energy and protein supplements. Furthermore, the increased forage quality from such a four-cut schedule can result in significantly more milk per acre than a three-cut schedule (Undersander et al., 2000).

If hay is being grown for market, where maximum tonnage is more valued than its forage quality, harvesting alfalfa at first flower may be the most profitable production strategy. Alfalfa grown for both feeding and marketing may be harvested at different growth stages, depending on the specific circumstances of the livestock enterprise and of market demand.

When alfalfa is grazed it results in good gains and carrying capacity (tables 21 and 22). However, it does cause bloat. Mixtures of alfalfa with grasses reduce the risk of bloat for grazing ruminants.

Alfalfa is frequently grown in crop rotation with non-legumes such as corn. It can supply important nitrogen and organic matter for use by the subsequent crop. The variety 'Nitro' was specifically developed to supply both forage and nitrogen in crop rotations. It is a non-dormant type which will not consistently overwinter in Minnesota (Sheaffer et al., 1989). For more information on alfalfa management see *Alfalfa and Alfalfa Management* (Hanson et al., 1988), and *Alfalfa Management Guide* (Undersander et al., 2000). Many alfalfa varieties are described in *Minnesota Varietal Trials Results* (annually revised by the Minnesota Agricultual Experiment Station).

CULTURAL PRACTICES FOR FORAGE LEGUMES

ESTABLISHMENT

Establishing small-seeded legumes is more challenging than for large-seeded annual crops such as corn and soybean, or for small grains. Seedlings are fragile and develop slowly (figure I). Time and resources spent in establishing long-term stands of forage legumes should be considered an investment that will provide returns for years to come.

SEED

To assure the quality of seed being purchased, it is important to purchase certified seed of a named variety. However, for forage legumes such as sweetclover and alsike clover, most seed is sold as unnamed common varieties. In addition, common seed is often purchased because it is less expensive than named varieties. The following information should be available on any seed tag or container:

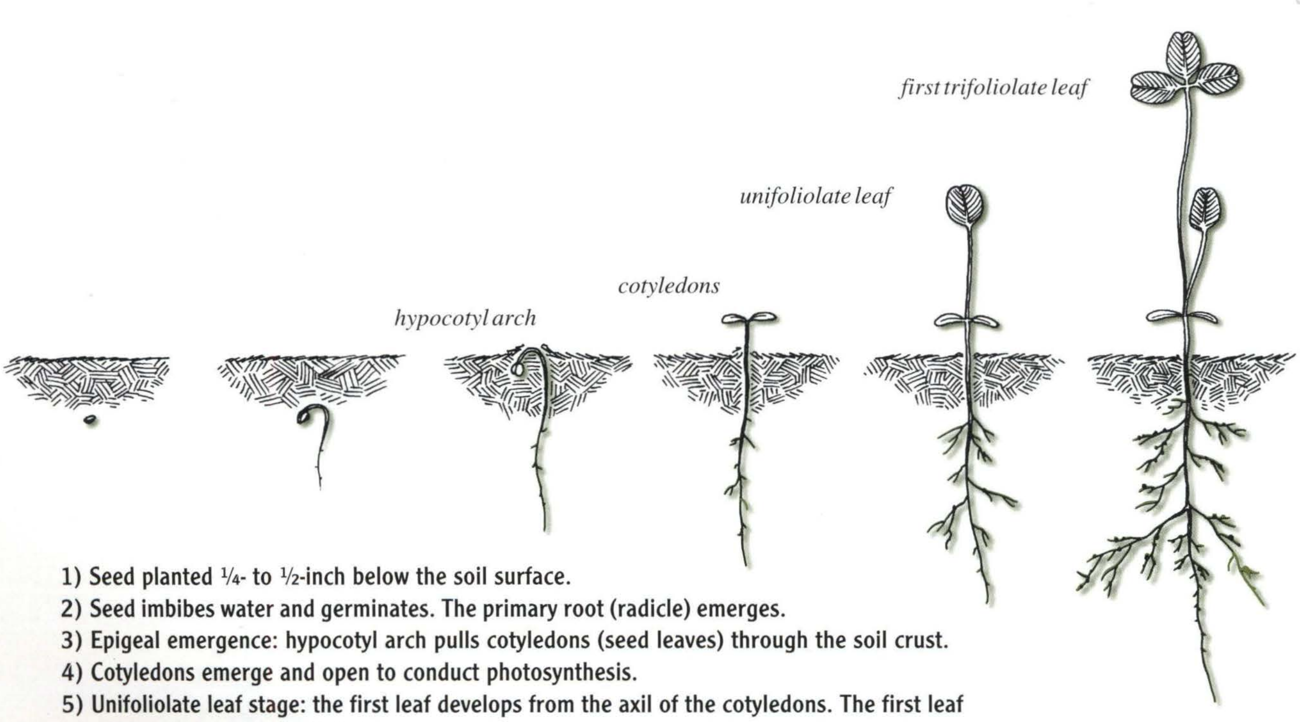
- variety name
- percent germination
- percent inert matter
- percent other crop seed
- percent weed seed
- crop species

From this information, seed costs can be evaluated based on the pure live seed content of a bag (figure J).

INOCULATION

To assure that legumes can conduct nitrogen fixation, growers should inoculate their seed with the proper *Rhizobium* bacteria or use preinoculated

Figure I. Distinct stages mark the development of a legume seedling such as a clover or alfalfa.



1) Seed planted ¼- to ½-inch below the soil surface.
2) Seed imbibes water and germinates. The primary root (radicle) emerges.
3) Epigeal emergence: hypocotyl arch pulls cotyledons (seed leaves) through the soil crust.
4) Cotyledons emerge and open to conduct photosynthesis.
5) Unifoliolate leaf stage: the first leaf develops from the axil of the cotyledons. The first leaf of birdsfoot trefoil is trifoliolate.
6) First trifoliolate leaf appears, cotyledons wither and later fall off. Stem elongation follows; a succession of leaves form on the stem.

Figure J. Formula used to evaluate and compare legume seed costs.

pure live seed % = (purity % X germination %)/100

where

purity % = 100 % – (inert matter % + other crop seed % + weed seed %)

seed. Inoculum can be purchased from seed vendors. Nitrogen fixing bacteria are specific for each species. Seed inoculation may be less important for widely grown legumes like red and white clover, but for relative new legumes like birdsfoot trefoil, cicer milkvetch, and kura clover, inoculation is essential.

SOIL FERTILITY

Alternative forage legumes are usually better adapted to low fertility soils than alfalfa. Many of the clovers and birdsfoot trefoil tolerate lower soil pH than alfalfa and are more economical to grow because lime is not required. However, alternative legumes have greater productivity if fertilized and grown at soil pH of 6 to 7. Soil testing is recommended, as is fertilization with nutrients and lime as needed.

Animal manures should be considered as an important source of nutrients for legumes. Manures can be applied before seeding or to established stands. Manure can be applied to established stands in early spring or immediately following cutting.

FIELD PREPARATION

For both tilled and minimum tilled establishment of legumes, planning for legume establishment should begin the year before seeding. Soil fertility should be tested, existing species and weeds evaluated, and other features of the field noted.

When appropriate, soil fertilizers or manures can be applied and weeds or competing plants controlled in the fall before seeding. The legume best adapted to field conditions and which meets user needs should be selected.

SEEDBED PREPARATION

A firm seedbed assuring good soil-seed contact and shallow seed placement is essential. Loose and uneven seedbeds are a major cause of establishment failure. The soil should be firm enough for a footprint to sink no deeper than one inch.

Legumes vary somewhat in their tolerance of poor seedbeds. Chances of seeding failure are much greater for small-seeded birdsfoot trefoil and kura clover than for the more vigorous red clover. For most seedbeds, firming with a cultipacker seeder or press-wheel drill enhances stand establishment.

PLANTING DEPTH

Shallow seeding of legumes is important. Legumes with very small seeds like white clover, alsike clover, kura clover, and birdsfoot trefoil should be carefully sown no deeper than ¼-inch. Other legumes should be sown from ¼- to ½-inch deep. Test your planter to assure that seeds are planted at the proper depth. Seeds sown either on the soil surface or deeper than ½-inch have little chance of developing into seedlings.

Cultipacker seeders most consistently assure shallow seed placement. If a grain drill with a legume seed box is used, the seed tubes should be positioned to deposit seed behind coulters or openers which seed small grains.

SEEDING RATES

Recommended seeding rates for the various alternative legumes are shown in table 25. With rough, not-firm seedbeds, the use of higher seeding rates can provide some advantages. More seeds develop into seedlings with the increased rates, howev-

Table 25. Seeding rates (pounds per acre) and seed characteristics of forage legumes.

Legume	Seeding rate for pure stand [a]	Seeding rate for grass mixture [a]	Seeds per lb	Seeds per sq ft [b]
Alfalfa	12	7	220,000	60
Alsike clover	5	2	700,000	64
Birdsfoot trefoil	10	7	375,000	69
Cicer milkvetch	12	5	130,000	35
Crownvetch	15	—	110,000	38
Kura clover	10	6	215,000	49
Red clover	10	5	275,000	63
Sweetclover	10	3	260,000	60
White clover	3	1	800,000	55

[a] Seeding rates are based on knowledge of seedling vigor of each species and target populations per square foot.

[b] When seeded in pure stands at recommended rate.

er, the added cost of using higher seeding rates needs to be considered. With good seedbeds and adequate moisture, the recommended seeding rates provide more than adequate plant populations per square foot, even if only half of the seeds develop into mature plants.

MIXTURES

Most perennial legumes are established in mixtures with perennial grasses. Mixtures with perennial grasses reduce the potential for bloat and enhance the drying rate of cut legumes. These mixtures may also reduce weed invasion. Recommended seeding rates for a variety of legume/perennial grass mixtures are shown in table 26. Alsike clover and white clover are frequently used as components of pasture mixtures with other legumes, but we generally do not recommend seeding more than one legume in a grass mixture.

Figure K. Legume seeding dates across region for spring and late-summer sowing.

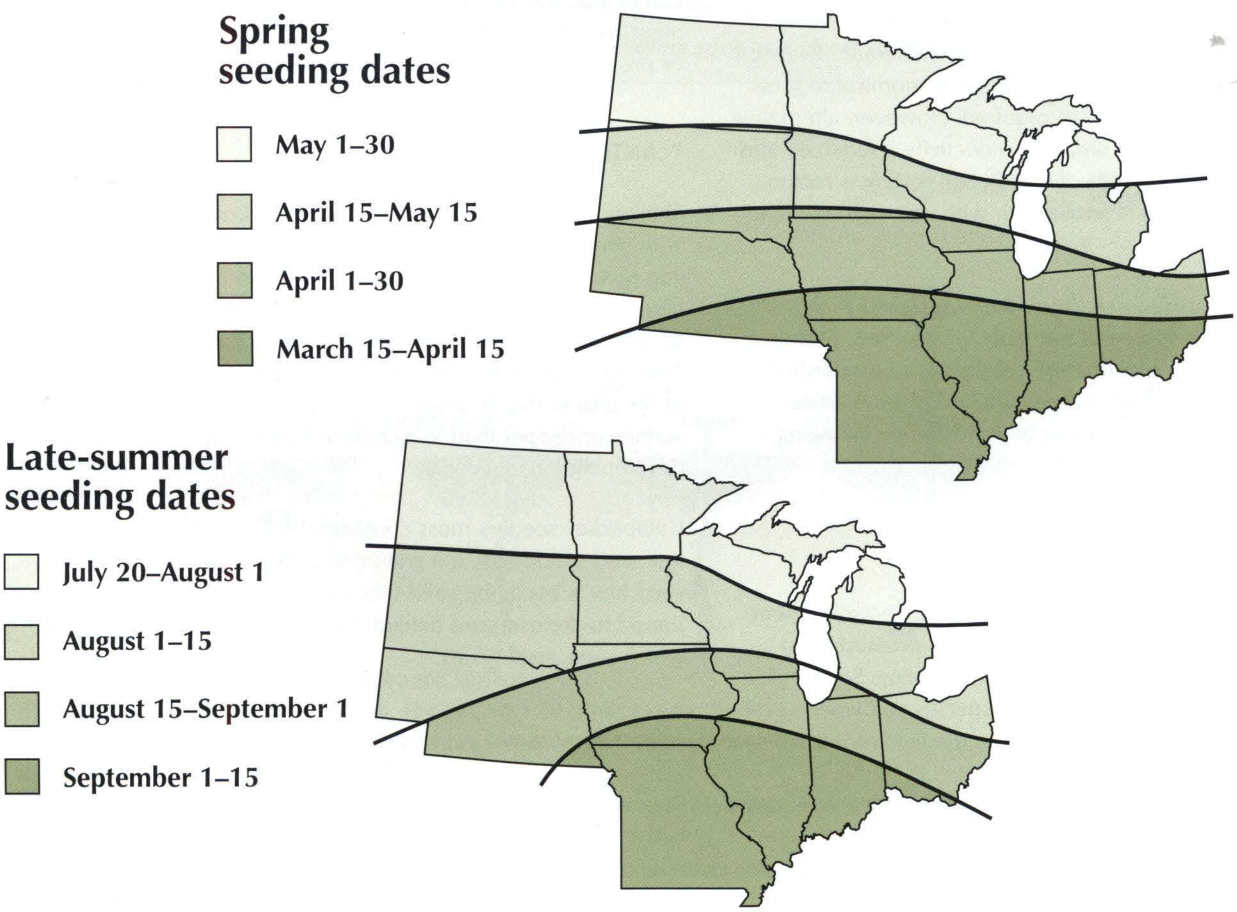


Table 26. Hay, silage and pasture mixture seeding rates suggested for Minnesota.

	Variety	Seeding Rate (lbs/acre)
1.	**Red clover or alfalfa**	7
	with	
	Orchardgrass	4
	or Smooth bromegrass	10
	or Reed Canarygrass	6
2.	**Red clover**	7
	Alsike clover	3
	Ladino clover	0.5
	with	
	Orchardgrass	4
	or Smooth bromegrass	10
3.	**Birdsfoot trefoil**	8
	with	
	Timothy	4
	or Reed canarygrass	6
4.	**Kura clover**	6
	Birdsfoot trefoil	2
	with	
	Orchardgrass	4
	or Reed canarygrass	6

TIME OF ESTABLISHMENT

A range of potential dates to optimize spring and summer seedings is shown in figure K. This is a figure similar to that shown in *Alfalfa Management Guide* (Undersander et al., 2000).

Spring seedings — Spring seedings are often practiced because they generally provide good soil moisture for germination and early seedling growth, a long growing season for establishment, and the potential for seeding year yields. Weed suppression via herbicides, companion crops, or clipping/grazing is required for spring seedings to reduce weed competition for light, nutrients, and water. Drought and high summer temperatures may limit seeding growth, and with late spring seedings may result in seedling mortality. Spring is the only option for no-till seeding of perennial legumes into grass sods.

Summer seedings — In regions where there are timely summer rainfall and cool fall temperatures, summer seedings can be very successful because there is less weed competition and seedling growth occurs in an ideal environment. Summer seedings are especially effective for legumes like kura clover that are poor competitors with weeds. Generally, companion crops or herbicides are not necessary for summer seedings. As noted below, if companion crops are necessary because of erosion problems, they can be killed with a grass herbicide when they reach a 4- to 8-inch height. Most legume seedlings require three trifoliolate leaves to survive the winter. Seeding beyond recommended seeded dates in the summer may result in injury or slow growth the following spring.

Late fall and winter seedings — Dormant or frost seedings at times outside of the normal growing season provide a low cost alterative approach that minimizes tillage and provides for early spring legume growth ahead of perennial and annual weeds, but are generally less successful than spring and summer seedings into tilled soil. On average, this is a successful approach for about 50 percent of the attempts. This strategy is most often used for pasture renovation or on sites where tillage is not possible. The strategy consists of broadcasting the seed on top of frozen soil when air temperatures are low enough to inhibit seed germination. Alternating periods of night-time freezing and daytime thawing bury the seed. Optimum times for dormant seedings are from November to March.

COMPANION CROPS

Perennial legumes and legume-grass mixtures can be seeded alone or with companion crops (nurse crops). Small grains such as spring oat, barley, and wheat are the most commonly used companion crops. When seeded without grasses in mixtures, herbicides can be used for weed control.

Small grain companion crops are excellent for reducing wind and water erosion of soil, but compete with legume seedlings for nutrients, moisture, and light. This competition may be especially critical for birdsfoot trefoil, kura clover, cicer milkvetch, and crownvetch, all of which lack seedling vigor. To reduce competition, small grain companion crops should be seeded at one-quarter to one-half of rates used for grain production, and any nitrogen fertilization should be limited to a maximum of 30 pounds per acre.

Allowing small grains to mature for grain frequently results in legume stand failure. Therefore, grazing of small grains when vegetative or harvest at boot stage for hay is recommended to further reduce competition. Windrows of straw or hay should be promptly removed to prevent smothering of legume seedlings.

WEED CONTROL

Spring seedings are more likely to encounter weed competition than summer seedings. Annual weeds are often eliminated by an early clipping or grazing (about 30 days after seeding). Herbicides are an alternative for weed control (consult Gunsolus et al., *Cultural and Chemical Weed Control in Field Crops,* Minnesota Extension Bulletin AG-BU-3157).

MINIMUM TILL SEEDING PASTURE RENOVATION

Legumes are frequently used for renovation of existing pastures. Practices that use plowing, disking, and harrowing to produce a firm seed bed will generally result in the best stands. However, for many permanent pastures, extensive tillage is not practical.

Specific strategies need to be employed for successful minimum till seeding:

- Test the soil and apply recommended levels of lime (for pH adjustment) and fertilizers. For older pastures, soil pH and fertility may be severely depleted. Application of lime at least six and up to 12 months prior to seeding will allow some movement into the soil.

- Control broad-leaved weeds and brush that can compete with new seedlings. Perennial broadleaf weeds such as the thistles can be a serious problem during pasture renovation. Once legumes are seeded, weeds are difficult to control because herbicide use is limited. For best results, control weeds during the preceding year. Follow state guidelines for herbicides to use.

- Suppress existing vegetation with grazing. Close and frequent grazing during the year before seeding will reduce vigor of existing grasses, thereby reducing their competition with legume seedlings. Hoof action will also expose the soil and enhance the effect of dormant and frost seeding.

- Apply herbicides to suppress grass growth. Several herbicides are available to suppress perennial grasses. Non-selective herbicides such as Roundup or paraquat are applied before interseeding whereas other herbicides that legumes have tolerance to, such as Pursuit, can be applied post-seeding to suppress grass. Consult University guidelines for herbicide recommendations.

Follow seeding date guidelines shown in figure K. When seeding into growing sods, spring seedings are preferred because summer seedings may be challenged by soil moisture deficits.

Use the appropriate seed delivery approach:

- For seedbeds that have been tilled and with less than about 25 percent surface residue or without intact sod, conventional grain drills and brillion seeders can be used. Assure that the seed is covered and not buried too deeply.

- For seedbeds with intact sod or high amounts of plant residue, specialized minimum- or no-till seeders are recommended. These seeders are engineered to provide heavy down pressure to plant at a uniform controlled depth, to cut openings into the sod and soil, and to provide soil coverage.

- For dormant or frost seedings, seed can be broadcast onto the soil surface by hand or a grain drill with raised openers. Freezing-thawing action of the soil and rainfall will bury the seed.

***Management of new seedings* —** Normally, legume seedings are first defoliolated at 50 to 60 days following emergence. However, original grasses and weeds can regrow and provide competition with seedings. When grass begins shading the legume seedings, use a heavy stocking rate on small areas (i.e., "mob graze") and attempt to graze to a 3- to 5-inch residual within a few days. Clipping or selective use of herbicides is an alternative approach.

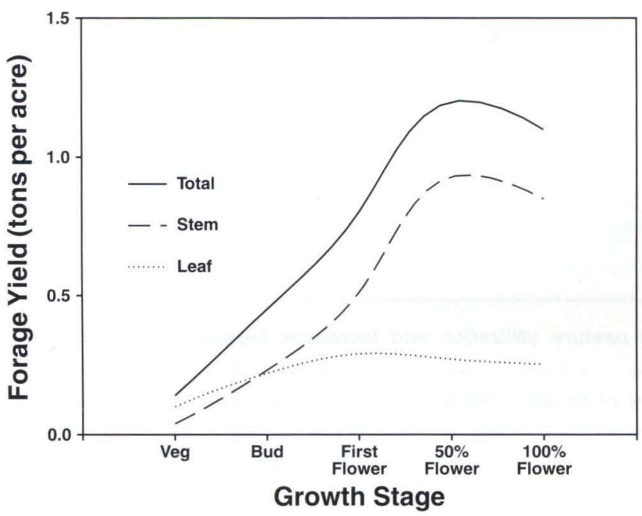
HAY AND SILAGE HARVEST MANAGEMENT

While yield increases with increased maturity, the forage quality of legumes decreases (figure L). Therefore, cutting schedules with more frequent harvests (e.g. a four-cut schedule) usually have greater nutrient concentrations but lower yields than with less frequent harvests (e.g., two- or three-cut schedules) (tables 6, 15, 16 and 19).

In contrast, persistence of most legumes is usually greatest for two- or three-cut schedules. Therefore, in deciding when to harvest legumes, consideration should be given to the relative importance of forage yield, forage quality, and stand persistence. Often perennial legumes are harvested for forage at early flowering stage as a compromise.

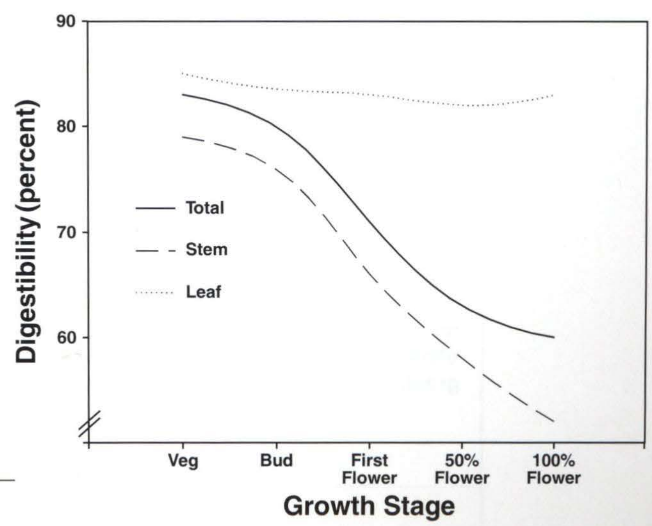
Upright legumes like alfalfa or red clover should have a minimum rest period of 30 days between cuttings. More frequent defoliation results in depletion of carbohydrate reserves and stand depletion. More prostrate legumes like ladino white clover, kura clover and cicer milkvetch, which have stems and leaf area escaping defoliation can tolerate more frequent cutting.

Figure L. Relationship between maturity of a selected legume (birdsfoot trefoil) to forage yield and its digestibility. [a]



(above) The relationship between birdsfoot trefoil maturity and yield of leaves, stems and the total forage. Note that with maturity beyond the bud stage, the increases in forage yield are due to a greater proportion of stem, while leaf yield has little change.

(below) The relationship between birdsfoot trefoil maturity and digestibility of leaves, stems and the total forage. Legume leaves are consistently higher in quality than stems, and decline little in digestibility with maturity.



[a] Source: McGraw and Marten. *1986. Agron. J.* 78:704-710.

GRAZING MANAGEMENT

Rotational and continuous grazing are the two primary grazing strategies used by producers. In continuous grazing, animals are placed on pastures for indefinite periods of time and allowed to select what forage they consume (i.e., the animals manage your pastures). Continuous grazing results in an uneven distribution of forage intake throughout the grazing season and poor persistence of most legumes (figure M).

In contrast, rotational grazing moves grazing animals among paddocks, controlling their selection of forage. To obtain both the most effective utilization and the persistence of a legume stand, animals should be rotationally grazed.

Several factors influence efficient legume use in pastures, including grazing and rest periods, height of grazing and stocking rate.

GRAZING AND REST PERIODS

Grazing of erect legumes like alfalfa, birdsfoot trefoil, and red clover should be iniated when vegetative at 10 to14 inches in height. Short legumes like white clover and kura clover should be grazed when five to eight inches high.

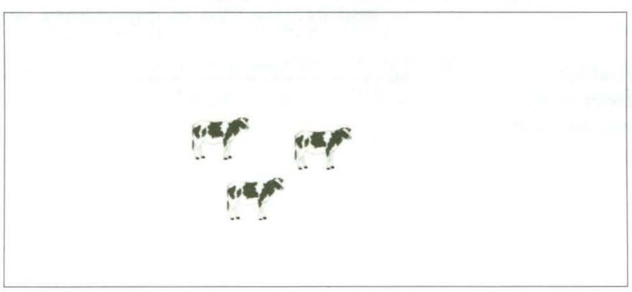
Following grazing, most grasses and legumes will begin their regrowth within a week. Short grazing periods, fron one-half to three days, will limit animal grazing of the regrowth and will enhance the persistence of desired forages. Grazing periods greater than a week and continuous grazing are especially detrimental to the persistence of palatable legumes because livestock actively seek and graze them.

Forage legumes like alfalfa, red clover, and birdsfoot trefoil will not usually persist without a four week rest period for replenishment of reserves. That's why in continuous grazed pastures only perennial grasses or prostrate legumes, like white clover, are usually present after a few years of grazing.

Since legume development can be affected by temperature, drought, and fertility, it is important that you let plant development tell you when to

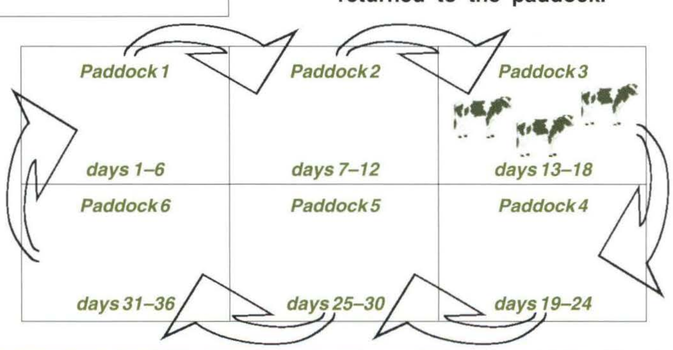
Figure M. Rotational grazing increases pasture utilization and increases legume persistence.

The number of paddocks and frequency of rotation depends on several factors: land resource, time of year, type of legume, type of livestock. For pasture design see *Pastures for Profit: A Guide to Rotational Grazing* (Undersander et al., 2002).



(*below*) Dividing a large pasture into six paddocks, each grazed for six days, provides plants with 30-days of rest before animals are returned to the paddock.

(*above*) Large continuously grazed pastures do not provide rest periods for plants. They often result in non-uniform grazing.



harvest. Legume grazing is usually initiated at vegetative stages.

HEIGHT OF GRAZING

The height of forage after it has been grazed is important only with rotational grazing, because in uncontrolled continuous grazing animals eat whatever forage they like. The height of grazing influences the amount of ungrazed leaf area, and consequently the rate of regrowth – the higher the stubble, the more rapidly the plant will regrow following grazing.

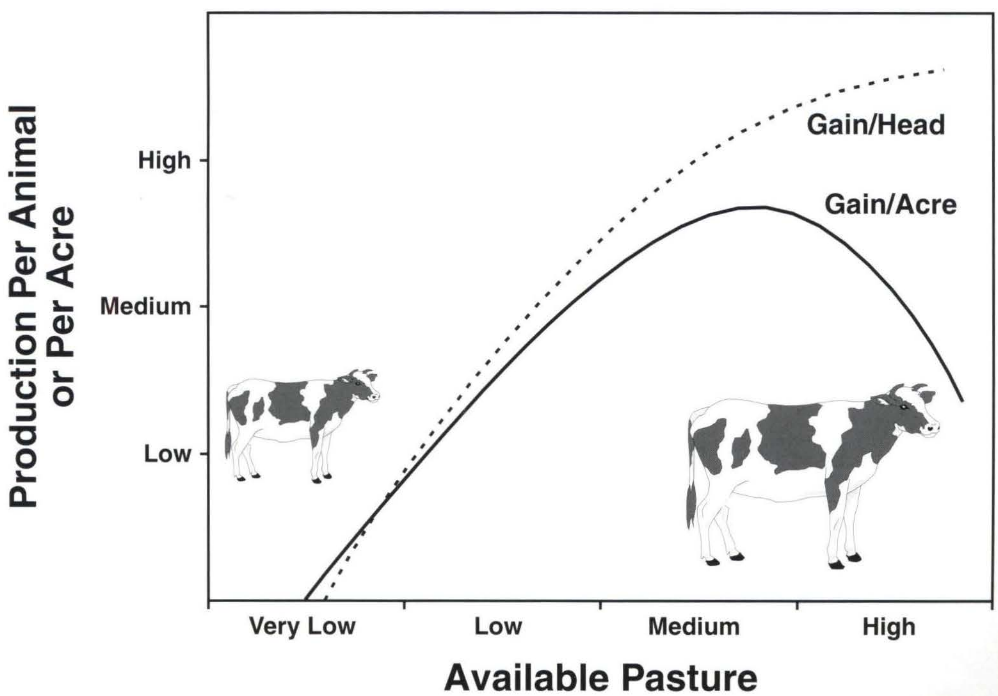
Using a four week rest interval, most legumes should be grazed to between two and four inches of stubble height. Increasing the stubble height will allow a more rapid regrowth and will enhance the legume's persistence.

Since forage at the top of plants is usually the highest in quality, the height of grazing can also influence animal performance. For animals with high nutritional needs, such as lambs, energy intake can be increased by allowing the animals to eat only the tops of plants. Forward creep feeding is an example of how this type of grazing management could be conducted. It would allow those animals with the higher energy needs to have first access to pastures before ewes.

STOCKING RATE

Stocking rates greatly influence yield per acre and per head (figure N). At low stocking rates (high available pasture), high gain per head occurs because animals are able to select high quality forage, but yield per acre is low because much of the available forage is wasted. At higher stocking rates (low available pasture), competition among animals for forage increases, selectivity decreases, and gain per head decreases.

Figure N. The relationship between available pasture and relative production per animal and per acre. As pasture availability increases, performance per head increases because animals can select the highest quality forage. However, gain or production per acre decreases at high levels of available pasture because of incomplete consumption of the available forage.



APPENDIX A: TABLES 4 THROUGH 24

USING LEAST SIGNIFICANT DIFERENCES

For many of the tables in this appendix, a "least significant difference" (LSD) value of 0.05 is often shown. LSD values provide a statistical method of differentiating between two means.

Use of an LSD statistic minimizes the risk of drawing a false conclusion. If a difference between two means exceeds their LSD value, then those means are considered to be significantly different. The 0.05 designation indicates that you can be 95 percent certain that the difference you are seeing is a real difference between treatments, between varieties, etc., and not just a difference due to random error or outside factors.

For example, in table 5 below, Endura's whole plant yield of 4,659 pounds per acre at Saint Paul exceeded the yield from Rhizo by more than the 187 pounds calculated as the least significant difference. This means that 95 percent of the time, when planted under these conditions, we can expect Endura to outperform Rhizo.

Table 4. Kura clover yields (tons per acre) over a six-year period in Lancaster and Marshfield, Wisconsin, and over two different three-year periods at Rosemount, Minnesota. (Significance of differences calculated within columns. [a])

Variety	Lancaster	Marshfield	Rosemount 1996-98	Rosemount 2000-01
Rhizo	3.3 b	2.9 b	2.9 b	3.6 b
Cossack	3.3 b	3.0 ab	3.3 a	4.1 ab
Endura	3.5 a	3.2 a	3.5 a	3.9 ab
NF-93	3.5 a	3.0 ab	3.5 a	4.4 a

[a] Within *columns*, means followed by the same letter are not significantly different from others with that same letter (Fisher's protected LSD=0.05).

Table 5. Total plant herbage root and rhizome dry matter yield (pounds per acre) from an October harvest of spring-seeded kura clover on two soils, one a high fertility silt loam (St. Paul, Minnesota) and the other a sandy loam (Becker, Minnesota). Root biomass includes roots, crowns, and rhizomes in 0–15 cm of the soil. [a]

Site/Variety	Whole Plant	Herbage	Root [b]	Rhizome [c]
St. Paul				
Endura	**4,659**	**2,088**	**2,571**	**353**
Rhizo	**3,698**	**1,085**	**2,612**	**289**
LSD (0.05)	**187**	**106**	**NS**	**45**
Becker				
Endura	**2,875**	**1,526**	**2,348**	**212**
Rhizo	**3,469**	**1,259**	**2,209**	**185**
LSD (0.05)	**295**	**116**	**NS**	**8**

[a] Source: Genrich et al., 1998. Crop Sci. 38:735–741.

[b] Root biomass includes roots, crowns, and rhizomes in 0–15 cm of the soil.

[c] Rhizomes were included as a fraction of the root yield.

Table 6. Effect of cutting schedules on forage yield (ton per acre) and final stands (percent) of perennial legumes at Rosemount, Minnesota.

Cut/year [a]	Legume [b]	Forage Yield 1985	1986	1987 [c]	3-yr total	Stand [c]
2-cut	Alfalfa	4.6	4.9	2.0	11.5 (100) [d]	53
	Alsike clover	2.1	2.1	—	4.2 (37)	5
	Red clover	3.8	4.8	—	8.6 (75)	10
	Crownvetch	1.9	4.1	—	6.0 (52)	24
	Cicer milkvetch	4.7	4.4	1.2	10.3 (90)	53
	Birdsfoot trefoil	4.5	4.6	0.8	9.9 (86)	30
	Kura clover	2.8	3.3	1.7	7.8 (68)	95
	LSD (0.05)	0.4	0.5	0.8		14
3-cut	Alfalfa	6.2	5.2	2.0	13.4 (100)	54
	Alsike clover	2.2	0.6	—	2.8 (21)	10
	Red clover	3.4	4.4	—	7.8 (58)	11
	Crownvetch	2.0	3.5	—	5.5 (41)	15
	Cicer milkvetch	4.3	4.4	1.3	10.0 (75)	75
	Birdsfoot trefoil	4.1	4.1	1.6	9.8 (73)	29
	Kura clover	2.8	4.1	1.8	8.7 (65)	95
	LSD (0.05)	0.2	0.4	0.4		18
4-cut	Alfalfa	5.5	4.9	1.6	12.0 (100)	38
	Alsike clover	1.6	0.7	—	2.3 (19)	5
	Red clover	2.8	3.7	—	6.5 (54)	9
	Crownvetch	1.7	3.3	—	5.0 (42)	18
	Cicer milkvetch	3.3	3.8	0.9	8.0 (67)	48
	Birdsfoot trefoil	3.4	4.0	0.1	7.5 (62)	9
	Kura clover	2.1	4.1	1.5	7.7 (64)	91
	LSD (0.05)	0.3	0.4	0.4		16

[a] Cut/year: 2-cuts at full flower (June 15, August 24); 3-cuts at bud-early flower (June 5, July 15, September 1); 4-cuts at vegetative-bud (May 28, June 26, July 27, September 1).

[b] 'DK-120' alfalfa, 'Common' alsike, 'Arlington' red clover, 'Penngift' crownvetch, 'Monarch' cicer milkvetch, 'Norcen' birdsfoot trefoil, 'Rhizo' kura clover.

[c] Forage yields from a harvest of all plots in early June; final stands estimated in May 1987.

[d] Values in parenthesis are percentage of alfalfa total yield for each cutting schedule.

Table 7. Herbage dry matter yield; forage crude protein (CP) concentration; and forage relative feed value (RFV) of five legumes. Legumes were managed with or without checkbook irrigation system at Becker, Minnesota, in 2000.

		Dry Matter Yield (tons per acre)				Forage Quality (July 6) [a]	
	Species	May 24	July 6	August 18	Total	CP %	RFV Index
Irrigated	Endura kura clover	1.0	1.4	1.4	3.7	20.2	173
	5454 alfalfa	2.1	1.7	1.8	5.7	17.4	111
	Marathon red clover	0.9	1.4	1.4	3.9	19.8	167
	Norcen birdsfoot trefoil	1.3	1.5	1.3	4.3	18.0	139
	Windsor cicer milkvetch	1.3	1.2	1.2	3.7	21.1	159
	LSD (0.05)	0.4	0.1	0.2	0.4	0.7	10
Drought	Endura kura clover	0.6	0.6	0.1	1.4	18.7	196
	5454 alfalfa	1.9	0.7	0.4	3.1	14.8	133
	Marathon red clover	0.8	0.8	0.2	1.9	17.1	182
	Norcen birdsfoot trefoil	1.0	0.6	0.2	2.0	14.7	197
	Windsor cicer milkvetch	1.2	0.7	0.1	2.1	17.7	176
	LSD (0.05)	0.1	0.1	0.0	0.3	0.6	9
	Irrigation trt. LSD (0.05)	0.2	0.1	0.1	0.1	0.1	1
	(Irr. x Spc.) interaction LSD (0.05)	NS	0.1	0.1	0.3	0.6	9

[a] CP = crude protein; RFV = relative feed value (a measure of potential energy intake).

Table 8. Effect of cutting schedules on season average yield (tons per acre) and forage quality (percent of dry matter) of kura clover (averaged over two years), for crude protein (CP), in vitro digestible dry matter (IVDDM), and neutral detergent fiber (NDF) concentration. [a]

Cuts/year	Yield	CP	NDF	IVDDM
3	4.0	22.2	32.6	85.4
4	4.1	23.7	30.5	86.9
5	4.0	24.9	29.8	88.0
6	4.0	25.4	29.5	87.9
LSD (0.05)	NS	0.5	0.4	0.4

[a] Source: Peterson et al., 1994. Agron. J. 86:655-660.

Table 9. Performance of Holstein steers on clover/grass pastures near Lancaster, Wisconsin. Values are means over three years, 1998-2000.

Treatment	Kura Clover /Grass	Red Clover /Grass
Grazing Days	169	169
Steer Days (per acre/year)	345	313
Average Daily Gain (pounds/day)	2.65	2.26
Gain (pounds/acre/year)	916	712

Table 10. Average total season leafiness, crude protein, digestibility, and neutral detergent fiber concentration of birdsfoot trefoil and kura clover forage, and lamb performance grazing these forages at St. Paul, Minnesota. [a b]

Trait	Kura clover	Birdsfoot trefoil
Forage quality		
Leafiness (%)	96.5 [c]	80.8
Crude protein (%)	25.2	22.2
Digestibility (%)	82.7 [c]	72.4
Neutral detergent fiber (%)	30.8	33.1
Lamb performance		
Average daily gain (lb)	0.47	0.43
Grazing days/acre	1664	1460
Season gain lb/acre	782 [c]	628

[a] Source: Sheaffer et al. 1992. *Agron. J.* 84:176-180.

[b] Values are averaged for 4 production years.

[c] Statistically significant differences between species.

Table 11. Long-term performance of 'Rhizo' kura clover monoculture and mixtures with grasses near Arlington, Wisconsin. Values presented are means over years one through three, and years four through six, of a long-term trial, and are averaged over three harvest frequencies and two stubble heights.

	Years 1–3				Years 4–6			
	Yield	Kura	NDF	CP	Yield	Kura	NDF	CP
	tons/acre [a]	— percent [b] —			tons/acre [a]	— percent [b] —		
Kentucky bluegrass/kura clover	2.8	60	41	19	3.3	66	38	19
Smooth bromegrass/kura clover	2.7	48	41	18	3.1	63	37	19
Orchardgrass/kura clover	2.6	44	44	19	2.9	54	40	18
Monoculture kura clover	2.3	100	29	23	2.8	100	30	22

[a] All harvests were completed by September 1 and autumn growth is not included in these figures.

[b] Kura = percent of kura clover in yield; NDF = neutral detergent fiber concentration; CP = crude protein.

Table 12. Whole corn plant dry matter and grain yield of corn grown with a kura clover living mulch near Arlington, Wisconsin, in 1999 and 2000. [a]

Corn/Kura treatment at planting	Whole Plant Yield (tons per acre) 1999	2000	Corn Grain Yield (bushels per acre) 1999	2000
Roundup Ready Corn				
in monoculture [b]	8.5 a	9.2 a	189 a	201 a
in living mulch [c]	7.5 a	8.5 a	176 ab	184 a
Liberty Link Corn				
in monoculture [b]	8.4 a	8.8 a	185 a	200 a
in living mulch [d]	7.5 a	8.1 a	170 b	192 a

[a] Within *columns*, means followed by the same letter are not significantly different from others with that same letter (LSD=0.05).

[b] Corn sown into killed kura clover sod.

[c] Kura clover suppressed with Roundup at time of sowing, with a second application of Roundup applied 30 days after.

[d] Kura clover suppressed with Roundup at time of sowing, with an application of Liberty herbicide 30 days after.

Table 13. Forage yield (tons per acre) and final stands (percent) of red clover varieties at Grand Rapids, Minnesota. [a]

	Forage Yield						Stands	
	1990		1991		1992		June 9, 1992	
Variety	3-cuts	2-cuts	3-cuts	2-cuts	3-cuts	2-cuts	3-cuts	2-cuts
Atlas	1.88	2.78	2.45	2.63	1.24	2.17	79	93
Arlington	1.54	2.00	1.65	1.67	0.67	1.28	18	59
Florex	1.98	3.29	2.55	2.84	1.13	2.30	73	91
Lakeland	1.96	3.26	2.12	2.87	0.80	1.89	54	90
Marathon	2.36	3.30	2.97	2.72	1.77	2.33	86	90
Prosper I	1.89	3.21	2.33	2.80	1.09	2.28	58	95
Average	1.94	2.97	2.34	2.59	1.12	2.04	61	86
LSD (0.05)	0.45		0.41		0.35		16	

[a] Legumes established in 1989 and cut on June 20, July 25, September 15 (for 3-cuts); or cut June 28 and August 15 (for 2-cuts).

Table 14. Red clover, ladino clover and alsike clover forage yields (tons per acre) and stands (percent) at Grand Rapids, Minnesota.[a]

Legume	Forage yield 1989	Forage yield 1990	Forage yield 2-yr total	Stands 1991
Red clover				
Common (medium)	3.8	1.5	5.3 (100)[b]	60[c]
Marathon	4.3	2.1	6.3 (119)	80
Arlington	4.1	1.9	6.0 (113)	80
Atlas	3.5	2.2	5.7 (108)	75
Ladino clover				
Sacramento	1.9	1.3	3.2 (100)	10
Osceola	2.4	1.3	3.7 (123)	5
Merit 3	2.3	1.6	3.9 (130)	0
Arcadia	2.3	1.4	3.7 (123)	0
Alsike clover				
Common	2.9	1.3	4.2 (100)	0

[a] Legumes established in 1988 and cut on June 28 and August 15 at flowering in 1989 and 1990.

[b] Percent of common red clover or Sacramento ladino clover yield.

[c] Stands in May 1991.

Table 15. Effect of cutting schedules on forage yield (tons per acre) and final stands (percent) of perennial legumes at Grand Rapids, Minnesota.

Schedule[a]	Legume[b]	Forage yield 1987	Forage yield 1988	Forage yield 2-yr total	Stands[c] 1987	Stands[c] 1988
2-cut	Alfalfa	3.6	2.9	6.5 (100)[d]	84	66
	Alsike clover	2.1	—	2.1 (32)	74	1
	Red clover	4.7	1.5	6.2 (95)	92	75
	Cicer milkvetch	2.3	1.2	3.5 (54)	69	48
	White clover	2.2	0.1	2.3 (35)	91	23
	Birdsfoot trefoil	3.8	0.8	4.6 (71)	93	73
	Crownvetch	1.6	0.2	1.8 (28)	33	28
	LSD (0.05)	0.4	0.6		9	15
3-cut	Alfalfa	4.0	3.0	7.0(100)	85	74
	Alsike clover	1.2	—	1.2 (17)	70	1
	Red clover	4.0	1.6	5.6 (80)	93	84
	Cicer milkvetch	2.6	2.1	4.7 (67)	83	71
	White clover	2.0	0.1	2.1 (30)	93	35
	Birdsfoot trefoil	3.3	2.9	6.2 (89)	94	76
	Crownvetch	1.1	0.5	1.6 (23)	28	21
	LSD (0.05)	0.4	0.9		9	15

[a] Cut/year: 2-cuts at full flower (June 15, August 24); 3-cuts at bud-early flower (June 5, July 15, September 1).

[b] 'DK-120' alfalfa, 'Common' alsike, 'Arlington' red clover, 'Penngift' crownvetch, 'Monarch' cicer milkvetch, 'Norcen' birdsfoot trefoil, 'Sacramento' ladino clover.

[c] Final stands in May 1988.

[d] Values in parenthesis are percentage of alfalfa total yield for each cutting schedule.

Table 16. Effect of cutting schedules on forage yield (tons per acre) and final stands (percent) of perennial forage legumes at Lamberton, Minnesota.

Cut/year [a]	Legume [b]	Forage Yield 1987	1988	1989 [c]	3-yr total	Stand [c]
2-cuts	Alfalfa	5.4	4.1	3.2	12.7 (100) [d]	90
	White clover	2.1	0.4	—	2.5 (20)	53
	Alsike clover	3.5	—	—	3.5 (28)	—
	Red clover	4.8	2.4	1.1	8.3 (65)	36
	Crownvetch	3.9	2.9	1.5	8.3 (65)	69
	Cicer milkvetch	4.9	3.2	2.2	10.3 (81)	88
	Birdsfoot trefoil	5.6	3.4	2.1	11.1 (87)	86
	LSD (0.05)	0.7	0.5	0.4		21
3-cuts	Alfalfa	6.1	4.8	2.6	13.5 (100)	92
	White clover	2.2	0.3	—	2.5 (18)	50
	Alsike clover	3.1	—	—	3.1 (23)	—
	Red clover	5.8	2.4	1.1	9.3 (69)	50
	Crownvetch	3.3	2.0	0.9	6.2 (46)	87
	Cicer milkvetch	3.9	2.4	1.5	7.8 (58)	89
	Birdsfoot trefoil	5.3	3.1	1.5	9.9 (73)	91
	LSD (0.05)	0.6	0.4	0.3		8
4-cuts	Alfalfa	6.3	4.5	3.1	13.9 (100)	92
	White clover	2.5	0.4	—	2.9 (21)	43
	Alsike clover	2.7	—	—	2.7 (19)	—
	Red clover	5.2	2.1	1.2	8.5 (61)	65
	Crownvetch	2.7	1.3	0.9	4.9 (35)	79
	Cicer milkvetch	2.8	1.6	1.2	5.6 (40)	85
	Birdsfoot trefoil	4.8	1.9	1.4	8.1 (58)	95
	LSD (0.05)	0.7	0.4	0.6		22

[a] Cut/year: 2-cuts at full flower (June 15, August 24); 3-cuts at bud-early flower (June 5, July 15, September 1); 4-cuts at vegetative-bud (May 28, June 26, July 27, September 1).

[b] 'DK-120' alfalfa, 'Common' alsike, 'Arlington' red clover, 'Penngift' crownvetch, 'Monarch' cicer milkvetch, 'Norcen' birdsfoot trefoil, 'Sacramento' ladino clover.

[c] Forage yields from a harvest of all plots in early June; final stands estimated in May 1989.

[d] Values in parenthesis are percentage of alfalfa total yield for each cutting schedule.

Table 17. Seeding year yield (tons per acre) of red clover and alfalfa sod-seeded at several rates (pounds per acre) into a smooth bromegrass and quackgrass sod at Rosemount, Minnesota. Soil pH was 5.9. [a] [b]

		Suppression [c]	
Legume	Seeding rate	low	high
Red clover	4	2.2	3.1
(Arlington)	8	2.1	3.4
	12	2.5	3.3
	16	2.5	3.3
Alfalfa	4	1.1	2.0
(Ramsey)	8	1.3	1.8
	12	1.5	1.7
	16	1.9	1.7
LSD (0.05)		0.9	0.9

[a] Source: Sheaffer and Swanson. 1982. *Agron. J.* 74:355-358.

[b] Legumes were seeded on or about May 15 each year into suppressed sod.

[c] Low and high grass suppressions were obtained by applying 0.5 and 1.5 lbs/acre of glyphosate 24 hours before interseeding of legumes.

Table 18. Mean (and range) stolon density, flowering intensity and vigor of 30 Wisconsin white clover ecotypes and six control varieties after three years of grazing in southern Wisconsin.

Line	Stolon density (no/sq ft)	Flowering [a]	Mean vigor [b]
Naturalized Wisconsin Ecotypes (mean)	169	3.3	80
(range)	96–276	2.4–4.8	61–117
California Ladino	84	4.2	100
Grasslands Huia	183	1.0	86
Grasslands Kopu II	217	2.6	137
SRVR	139	4.2	121
Tillman II	158	4.4	120
Will	173	3.8	110

[a] Flowering is scored on a scale from 1–5; 1 = greatest flowering; 5 = least flowering.

[b] Control (California Ladino) = 100.

Table 19. Effect of cutting schedules on average seasonal forage crude protein (CP), in vitro digestible dry matter (IVDDM), and neutral detergent fiber (NDF) concentration of perennial legumes at Lamberton, Minnesota.

Cuts [a]	Legume [b]	Percent dry weight CP	IVDDM	NDF
2-cut	Alfalfa	14.3	57.9	50.7
	Alsike clover	17.1	62.9	42.0
	Red clover	15.4	60.1	47.7
	Crownvetch	16.8	64.3	41.0
	Cicer milkvetch	16.5	62.5	40.1
	Birdsfoot trefoil	15.7	58.9	48.5
	White clover	19.9	65.8	35.7
	LSD (0.05)	1.0	1.4	2.1
3-cut	Alfalfa	17.1	62.2	43.4
	Alsike clover	21.5	69.1	31.2
	Red clover	18.8	64.5	40.2
	Crownvetch	20.5	66.2	35.9
	Cicer milkvetch	20.0	64.9	35.0
	Birdsfoot trefoil	20.1	63.0	37.7
	White clover	20.6	65.4	35.0
	LSD (0.05)	2.0	2.0	3.5
4-cut	Alfalfa	20.3	62.5	42.0
	Alsike clover	24.4	70.1	28.9
	Red clover	21.9	64.9	39.7
	Crownvetch	23.6	68.6	32.3
	Cicer milkvetch	22.9	66.6	32.1
	Birdsfoot trefoil	22.5	64.4	38.2
	White clover	23.4	67.5	31.1
	LSD (0.05)	0.9	1.4	2.1

[a] Cut/year: 2-cuts at full flower (June 15, August 24); 3-cuts at bud-early flower (June 5, July 15, September 1); 4-cuts at vegetative-bud (May 28, June 26, July 27, September 1).

[b] 'DK-120' alfalfa, 'Common' alsike, 'Arlington' red clover, 'Penngift' crownvetch, 'Monarch' cicer milkvetch, 'Norcen' birdsfoot trefoil, 'Sacramento' ladino clover.

Table 20. Forage yield (tons per acre) of varieties of birdsfoot trefoil, red clover and alfalfa seeded at Beaver Bay, Minnesota.[a]

Legume	Forage yield 1984	1985	2-year total	Percent of alfalfa yield
Birdsfoot trefoil				
Norcen	2.9	2.2	5.1	(364)
Leo	2.7	2.0	4.7	(336)
Maitland	2.8	1.2	4.0	(285)
Red clover				
Arlington	3.6	— [b]	3.6	(257)
Lakeland	2.8	— [b]	2.8	(200)
Alfalfa [c]	1.4	— [b]	1.4	(100)

[a] Legumes seeded in 1983 and cut on June 19, August 6, October 16, 1984, and June 20, July 31, October 6, 1985.

[b] Winter killed during 1984-85 winter.

[c] Very poor stand due to acid (pH < 6.0) and wet clay soil. Value is a mean of Vernal, Saranac AR, Iroquis, 532, and Trident alfalfa varieties.

Table 21. Lamb performance during grazing of four legumes. [a]

Year	Alfalfa	Birdsfoot trefoil	Red clover	Cicer milkvetch
Average daily gain (pounds)				
1985 [b]	.46 a	.45 a	.46 a	.55 a
1986	.41 a	.38 ab	.35 b	.43 a
1987	.48 b	.59 a	.54 a	.54 a
Lamb product per acre				
1985	760 b	733 b	877 a	656 b
1986	700 a	662 a	630 a	750 a
1987	636 a	594 bc	470 c	801 a

[a] Source: Marten et al. 1990. *Crop Sci.* 30:860-866.

[b] Means within rows followed by different letters are different (P=0.05; Fisher's LSD).

Table 22. Carrying capacity and heifer performance during grazing of three legume species during two seasons. [a]

Legume	Carry capacity (days/acre)	Cattle gain: Daily (lbs)	Cattle gain: Seasonal (lbs/acre)
Alfalfa	233 (100) [b]	1.5 (100)	349 (100)
Birdsfoot trefoil	215 (92)	1.8 (121)	387 (111)
Cicer milkvetch	269 (112)	0.9 (63)	251 (72)

[a] Source: Marten et al., 1987. *Crop Sci.* 27:138-145.

[b] Values in parenthesis are expressed as a percentage of alfalfa.

Table 23. Forage and nitrogen yield of three perennial legumes in the fall of the seeding year following an April planting. [a]

Legume	Forage	Crown	Root	Total
Forage yield (tons per acre)				
Alfalfa	1.8	0.5	0.8	3.1
Red clover	2.2	0.6	0.6	3.4
Sweetclover	2.2	0.5	2.2	4.9
LSD (0.05)	0.1	0.1	0.3	0.5
Nitrogen yield (pounds per acre)				
Alfalfa	87	37	49	173
Red clover	132	38	30	200
Sweetclover	130	23	156	309
LSD (0.05)	4	3	22	34

[a] Source: Groya and Sheaffer. 1985. *Agron. J.* 77:105-109.

Table 24. Total season forage yield and average forage quality of perennial legumes when grown with irrigation or drought on a sandy soil at Becker, Minnesota. *Forage quality is expressed as percentages of acid detergent fiber (ADF) and crude protein (CP).* [a]

Legume	Forage tons/acre: Irrigated	Forage tons/acre: Drought	Forage ADF %: Irrigated	Forage ADF %: Drought	Forage CP %: Irrigated	Forage CP %: Drought
Alfalfa	4.2 (100) [b]	2.6 (100)	36.7	33.0	19.3	19.5
Birdsfoot trefoil	3.0 (72)	1.5 (52)	35.0	24.9	20.9	23.2
Cicer milkvetch	2.8 (66)	1.6 (59)	32.4	25.1	22.7	21.5
Red clover	3.2 (75)	1.8 (69)	31.9	28.5	20.5	20.7
LSD (0.05) [c]	0.7	0.7	1.7	1.7	18.0	18.0

[a] Source: Peterson et al., 1992. *Agron. J.* 84:774-779.

[b] Values in parenthesis are yields as a percentage of alfalfa.

[c] LSD for comparison of two means within and over irrigated and drought conditions.

APPENDIX B: REFERENCES

Affeldt, R.P., K.A. Albrecht, C.M. Boerboom, and E.J. Bures. 2000. Integrating herbicide resistant corn living mulch system. p. 136. In *Agronomy Abst.* ASA, CSSA, SSSA, Madison, Wisc.

Cuomo, G.J., D.G. Johnson, and W.A. Head. 2001. Interseeding kura clover and birdsfoot trefoil into existing cool-season grass pastures. Agron. J. 93:458–462.

Date, R.A., and J. Brockwell. 1978. Rhizobium strain competitions and host interactions for nodulation. *In* J.R. Wilson (ed.) *Plant Relations in Pastures.* Commonwealth Scientific and Industrial Research Organization, East Melbourne, Australia.

Elling, L.J., R.L. McGraw, and D.L. Wyse. 1985. *Birdsfoot trefoil seed production in Northern Minnesota.* Minnesota Agricultural Extension Bulletin AG-FO-2678. University of Minnesota, St. Paul, Minn.

Genrich, K.C., C.C. Sheaffer, and N.J. Ehlke. 1998. Kura clover growth and development during the seeding year. *Crop Sci.* 38:735–741.

Groya, F.L., and C.C. Sheaffer. 1985. Nitrogen from forage legumes: harvest and tillage effects. *Agron. J.* 77:105–109.

Gunsolus, J.L., et al. (eds.) Annually Revised. *Cultural and Chemical Weed Control in Field Crops.* Minnesota Extension Bulletin AG-BU-3157-S. University of Minnesota, St. Paul, Minn.

Hanson, A.A., D.K. Barnes, and R.R. Hill, Jr. (eds.) 1988. Alfalfa and alfalfa improvement. *Agronomy* 29. American Society of Agronomy. Madison, Wisc.

Heichel, G.H. 1987. Legume nitrogen: Symbiotic fixation and recovery by subsequent crops. p. 63–80. *In* Z.R. Helsel (ed.) *Energy in Plant Nutrition and Pest Control.* Elsevier Science Pub., Amsterdam, Netherlands.

Hollowell, E.A. 1951. Ladino and other white clovers. *In* Hughes et al. (ed.) *Forages.* The Iowa State College Press. Ames, Iowa.

Justin, J.R., H.L. Thomas, A.R. Schmid, R.D. Wilcoxon, A.G. Peterson, and C.J. Overdahl. 1967. *Red Clover in Minnesota.* Minnesota Agricultural Extension Bulletin 343, University of Minnesota, St. Paul, Minn.

Marten, G.C., F.R. Ehle, and E.A. Ristau. 1987. Performance and photosensitization of cattle related to forage quality of forage legumes. *Crop Sci.* 27:138–145.

Marten, G.C., R.M. Jordan, and E.A. Ristau. 1990. Performance and adverse response of four legumes. *Crop Sci.* 30:860-866.

Martin, N.P., and O.E. Strand. 1978. *Sod seeding legumes into grass pasture.* Agronomy fact sheet 34–1978, Agricultural Extension Service, University of Minnesota, St. Paul, Minn.

McGraw, R.L., and G.C. Marten. 1986. Analysis of primary spring growth of four pasture legume species. *Agron. J.* 78:704–710.

Minnesota Varietal Trials Results. Annually Revised. Minnesota Agricultural Experiment Station Miscellaneous Publication, St. Paul, Minn.

Musser, H.B., W.L. Hottenstein, and J.P. Stanford. 1954. *Penngift Crownvetch for Slope Control on Pennsylvania Highways.* Pennsylvania State University Bulletin 576.

Pellet, F.C. 1945. That new clover. *Am. Bee J.* 85:394–395.

Peterson, P.R., C.C. Sheaffer, and M.H. Hall. 1992. Drought effects on perennial forage legume yield and quality. *Agron. J.* 84:774–779.

Peterson, P.R., C.C. Sheaffer, R.M. Jordan, and C.J. Christians. 1994. Responses of kura clover to sheep grazing and clipping: I. Yield and forage quality. *Agron. J.* 86:655–660.

Peterson, P.R., C.C. Sheaffer, R.M. Jordan, and C.J. Christians. 1994. Responses of kura clover to sheep grazing and clipping: II. Below-ground morphology, persistence, and total nonstructural carbohydrates. *Agron. J.* 86:660–667.

Piper, C.V. 1924. *Forage Plants and Their Culture.* The MacMillan Company, New York.

Hollowell, E.A. 1951. Ladino and other white clovers. *In* Hughes et al. (ed.) *Forages.* The Iowa State College Press. Ames, Iowa.

Seguin, P., M. P. Russelle, C.C. Sheaffer, N. J. Ehlke, and P.H. Graham. 2000. Dinitrogen fixation in kura clover and birdsfoot trefoil. *Agron. J.* 92:1216–1220.

Sheaffer, C.C., et al. 1989. *Annual alfalfa in crop rotations.* Minnesota Agricultural Experiment Station Bulletin 588–1989, University of Minnesota, St. Paul, Minn.

Sheaffer, C.C., and G.C. Marten. 1991. Kura clover forage yield, forage quality and stand dynamics. *Can. J. Plant Sci.* 71:1169–1172.

Sheaffer, C.C., G.C. Marten, R.M. Jordan, and E.A. Ristau. 1992. Forage potential of kura clover and birdsfoot trefoil when grazed by sheep. *Agron. J.* 84:176–180.

Sheaffer, C.C., and D.R. Swanson. 1982. Seeding rates and grass suppression for sod-seeded red clover and alfalfa. *Agron. J.* 74:355–358.

Smith, W.K., and H.J. Gorz. 1965. Sweetclover improvement. *Adv. Agronomy* 17:163–231.

Smoliak, S., and M. Bjorge. 1983. Hay and pasture crops. p. 7–40. *In Alberta Forage Manual.* Alberta Agriculture, Edmonton, Alberta, Canada.

Taylor, N.L. (ed.) 1985. Clover science and technology. *Agronomy* 25. American Society of Agronomy, Madison, Wisc.

Taylor, N.L. 1985. Red clover. p. 109–117. *In* M.E. Heath et al. *Forages: the Science of Grassland Agriculture.* Iowa State University Press. Ames, Iowa.

Taylor, N.L., and D. Henry. 1989. *Kura clover for Kentucky.* University of Kentucky Agricultural Experiment Station Publication AGR–141. Lexington, Ky.

Taylor, N.L., and R.R. Smith. 1998. Kura clover (*Trifolium ambiguum* Bieb.) breeding, culture, and utilization. *Adv. Agronomy* 63:154–178.

Thomas, H.L., E.R. Duncan, M.F. Kernkamp, A.G. Peterson, and A.R. Schmid. 1952. *Clovers for Minnesota.* Minnesota Agricultural Experiment Station Bulletin 415. University of Minnesota, St. Paul, Minn.

Townsend, C.E. 1985. Miscellaneous perennial clovers. p. 563–578. *In* N.L. Taylor (ed.) *Agronomy* 25. American Society of Agronomy. Madison, Wisc.

Undersander, D., B. Albert, D. Cosgrove, D. Johnson, and P. Peterson. 2002. *Pastures for Profit: A Guide to Rotational Grazing.* University of Wisconsin Cooperative Extension, A3529.

Undersander, D., N. Martin, D. Cosgrove, K. Kelling, M. Schmitt, J. Wedberg, R. Becker, C. Grau, J. Doll, and M. Rice. 2000. *Alfalfa Management Guide.* American Society of Agronomy, Madison, Wisc.

Wheeler, W.A. 1950. *Forage and Pasture Crops.* D. Van Nostrand Company, Inc., New York.

Zemenchik, R.A., K.A. Albrecht, C.M. Boerboom, and J.G. Lauer. 2000. Corn production with kura cloveras a living mulch. *Crop Sci.* 92:698-705.

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