UNIVERSITY OF MINNESOTA

Forage Legumes

Clovers, Birdsfoot Trefoil, Cicer Milkvetch, Crownvetch, Sainfoin and Alfalfa

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Using this publication

This publication is intended to serve both as an educational resource and a reference tool. To ease its use, some material is repeated in more than one section.

Because most tables are referenced commonly from many sections, tables 4 through 16 are grouped in a common appendix which begins on page 30.

Tables 1 through 3 are in the introductory section because they are specific to that general discussion. For similar reasons, tables 17 and 18 are within the section on cultural practices.

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INTRODUCTION

Legumes are plants which bear seeds in pods. The legume family *(Leguminosae, Fabaceae)* includes large seeded beans, peas, peanut, and soybean which produce seeds for use in human and livestock diets. Small seeded legumes, such as the clovers, birdsfoot trefoil, and alfalfa, produce vegetation for harvesting as forage. Forages are harvested by grazing livestock or by mechanical methods and are the primary component of most livestock rations.

Forage legumes are valuable crops in Minnesota and throughout 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.

Legumes are also well known as soil building plants. Earthworm populations are usually greater in fields planted to perennial forages than in fields planted to row crops.

If they are properly managed, forage legumes can convert unusable atmospheric nitrogen (78 percent of atmospheric gases by volume) into ammonia and ultimately into nutritionally valuable plant protein. This process is called symbiotic nitrogen fixation.

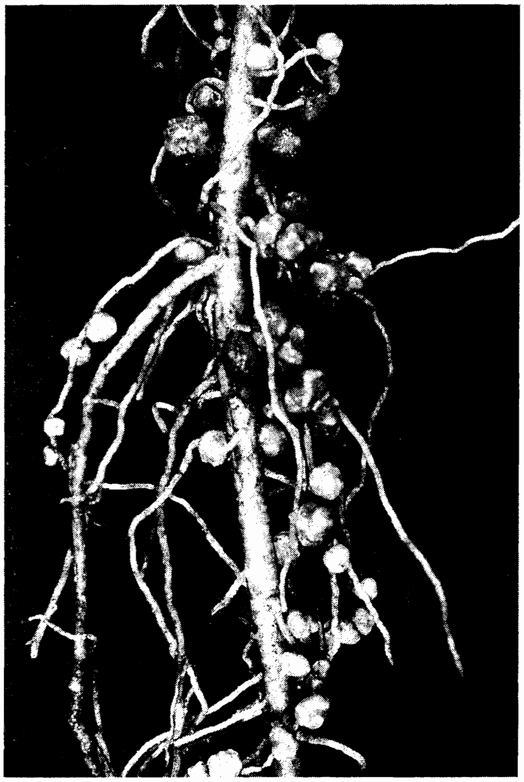
Symbiotic nitrogen fixation is a partnership between the legume plant and a bacteria *(Rhizobium)* which reside in nodules on legume roots (figure A). A legume plant also supplies nutrients and energy for the bacteria. The *Rhizobium* bacteria contains enzymes which conduct the nitrogen conversion process.

Legumes vary in their capacity to fix atmospheric nitrogen (table 1), but the result of nitrogen fixation is that legume forage and seed is consistently rich in protein while legume plants require no nitrogen fertilizer for growth. In addition, protein-nitrogen rich legume plants can be plowed under to supply nitrogen to subsequent crops in rotations.

In managing a legume as a green manure crop, the contribution of fixed nitrogen it makes to the soil depends on the quantity

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

(a) Birdsfoot trefoil



(b) Red clover

of nitrogen-rich forage incorporated. The roots of these plants are a relatively poor source of nitrogen.

Forage legume species differ in adaption to soil and climatic conditions and in their susceptibility to insect damage and diseases. As a result, the various types are each often best suited 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.

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

Legume Species	Nitrogen Fixed (pounds/acre/year)
Alfalfa	70-198
Birdsfoot trefoil	44-100
Crownvetch	98
Cicer milkvetch	140
Crimson clover	57
Fava bean	158-223
Field peas	155-174
Hairy vetch	99
Lentil	149-168
Red clover	60-115
Soybean	20-276
Sub clover	52-163
Sweetclover	120
White clover	115-180

[a] Source: Heichel (1987); Date and Brockwell (1978).

Table 2. Characteristics of forage legumes. [a]

Legume	Tolerance to: Heat/ drought	Wet	Winter hardiness	Frequent cutting/ grazing	Soil Salinity	Soil acidity	Soil alkalinity	Seeding vigor	Ruminant bloat inducing
Alfalfa	E	P	E	G	F	P	F	F	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	P	P	F	G	P	P	No
Kura clover	F	G	E	E	F	F	F	P	Yes
Red clover	F	F	F	F	F	F	P	E	Yes
Sainfoin	E	P	E	P	P	P	E	F	No
Sweetclover	E	P	E	P	G	P	E	G	Yes
White clover	P	F	P	G	F	F	P	F	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: Leaf hopper	Plant bugs	Leaf feeders	Crown & root feeders	Diseases: Damping off	Crown & root rot	Vascular wilts	Foliar disease	Virus	Nema-todes
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
Sainfoin	1	2	1	2	1	3	2	1	1	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

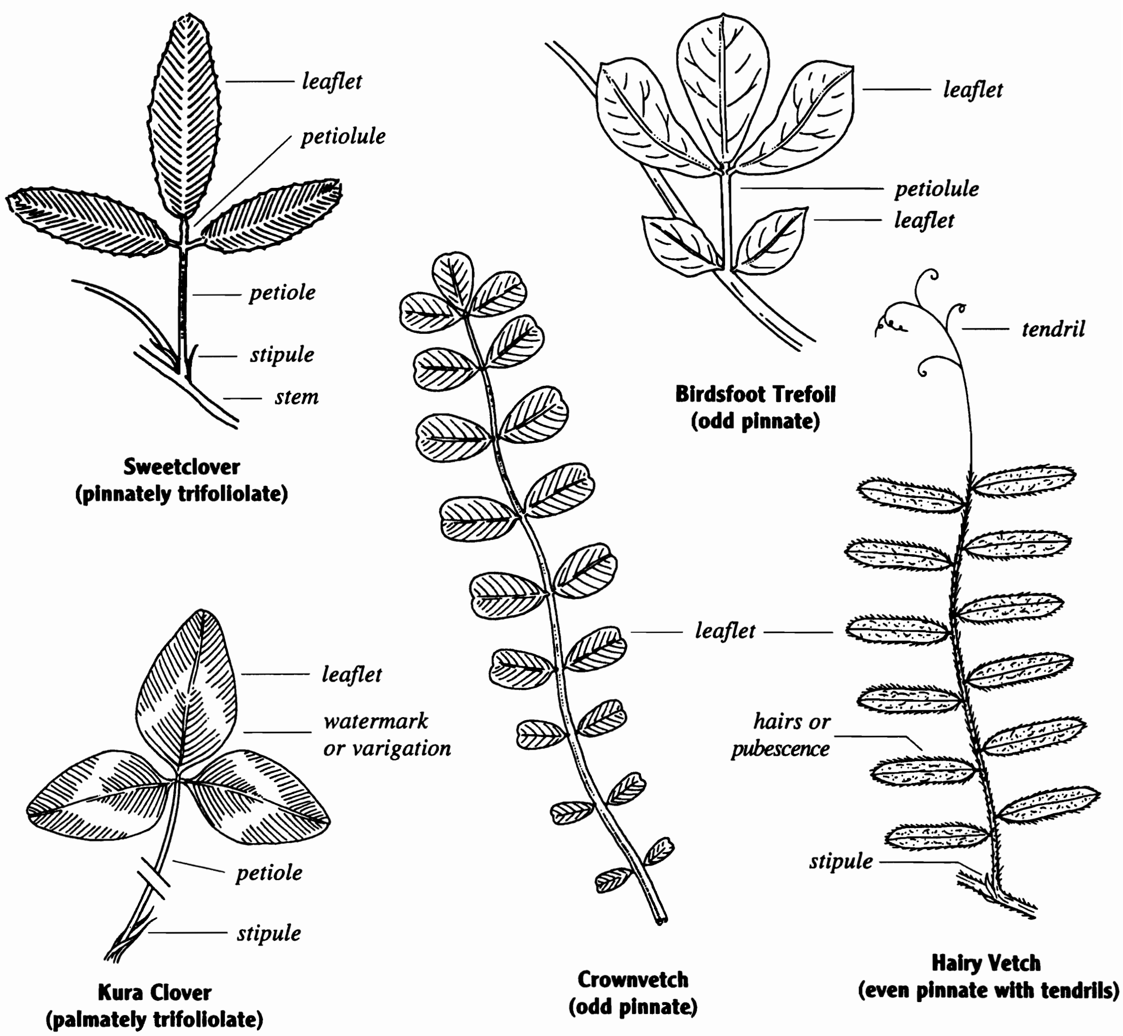
LEAVES

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). Leaf traits can be used to identify individual legume species.

Though leaves of clovers and alfalfa typically have three leaflets per leaf, they can sometimes be found with four or five leaflets. The frequency of four or more leaflets per leaf is influenced both by genetic makeup of the plant and the environment. Because they occur infrequently, "four leaf" clovers are considered to impart good luck.

There are four arrangements or organizations of leaflets on legume leaves that are commonly grown in the north central region. 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. Five typical leaf arrangements are shown (size not to scale).



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

FLOWERS

Legume flowers are usually showy and colorful. These features enhance the plants' ability to attract insect pollinators. Legume flower parts are the standard, 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 (red, white, alsike, and kura clover), raceme (alfalfa, sweetclover, cicer milkvetch), and umbel (birdsfoot trefoil, crownvetch). A head will typically contain many flowers while racemes and umbels contain few.

Properly pollinated, 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 harvesting. It is the site of an agricultural industry focused on commercial production of birdsfoot trefoil and clover seed.

ROOTS

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.

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

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

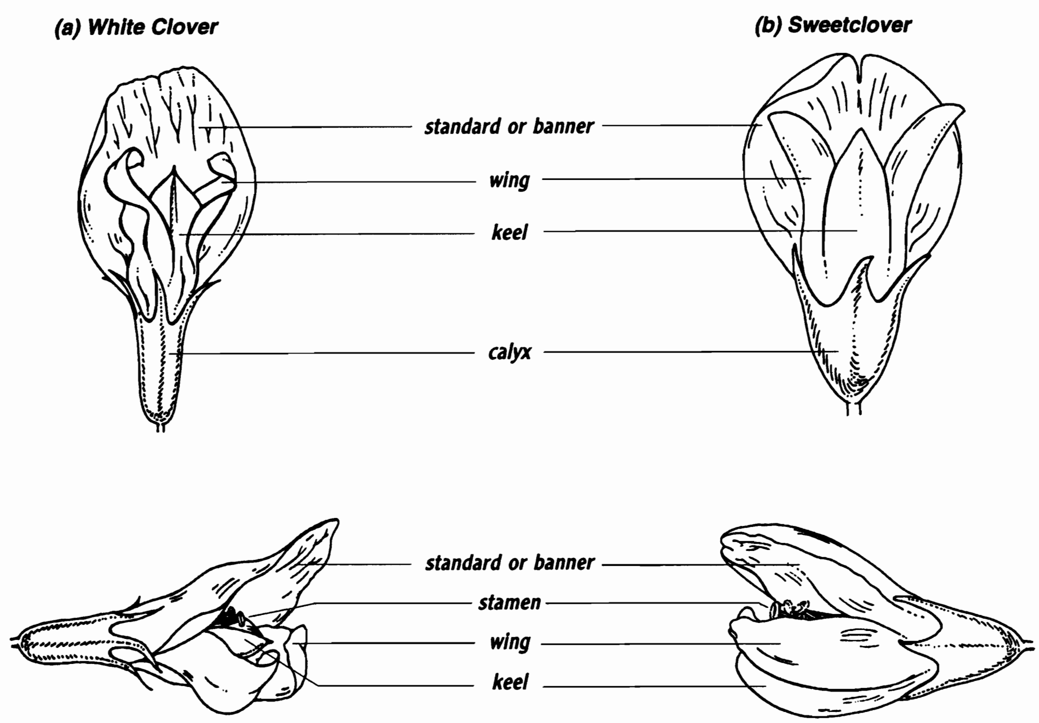
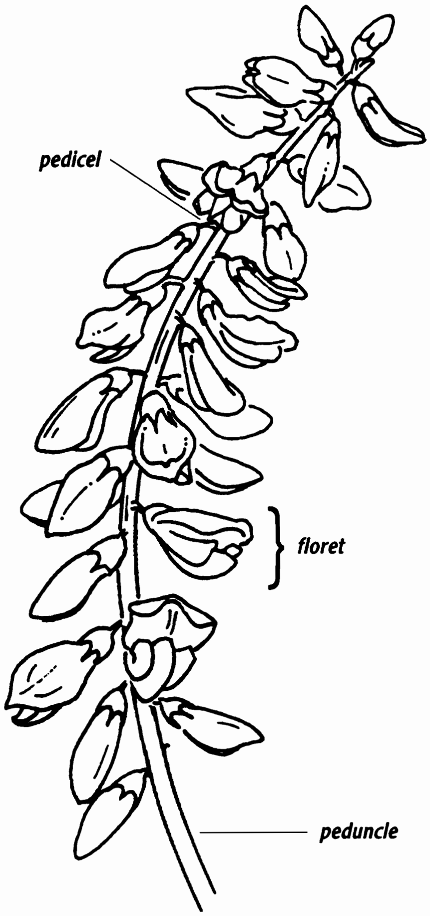
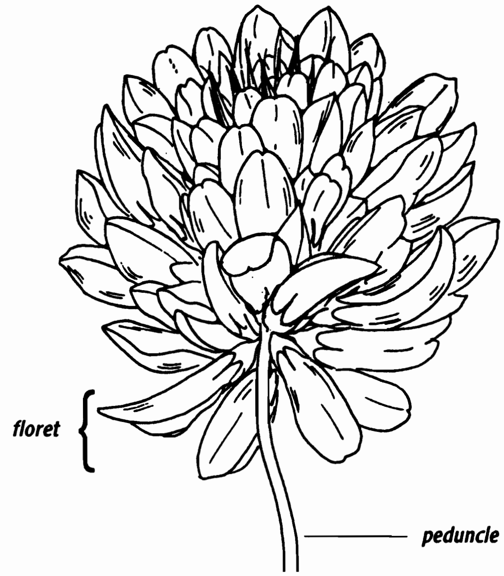


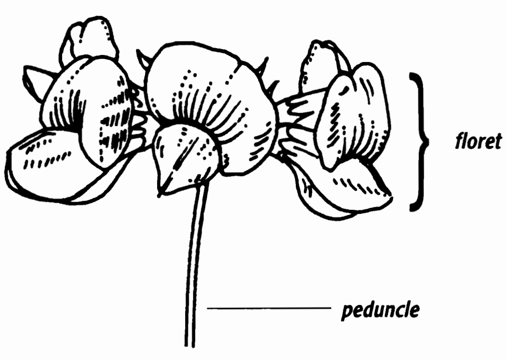
Figure D. Typical compound inflorescences of legumes.



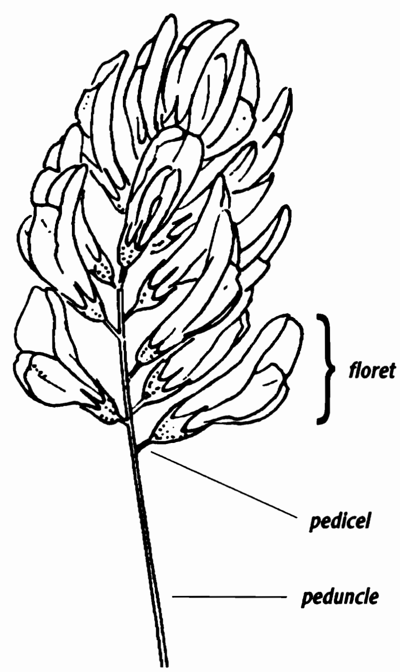
Sweetclover Raceme



Red or White Clover Head



Birdsfoot Trefoil Umbel

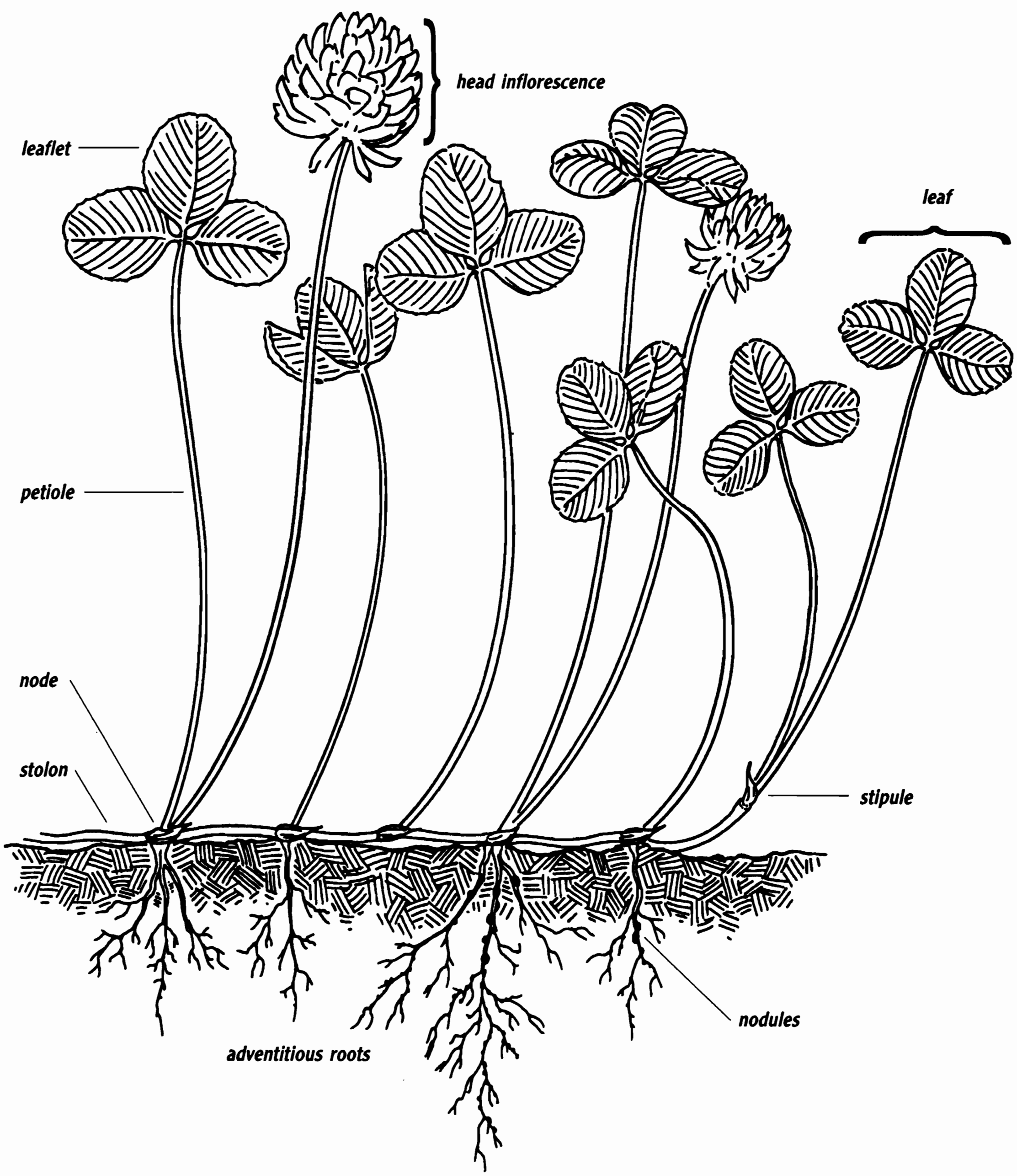


Alfalfa Raceme

STOLONS AND RHIZOMES

Stolons are horizontal above-ground stems (figure E). Rhizomes are 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, while rhizomes are found in kura clover, cicer milkvetch, and crownvetch. Legumes with rhizomes are among the most persistent species.

Figure E. White clover stolons illustrate vegetative spreading with the development of adventitious rooting from nodes in contact with soil.



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

There are two general types of red clover. Most red clover varieties grown in Minnesota are 'medium' or multiple cut types. The other type, mammoth red clover, is later flowering than medium red clover and produces only one crop of hay per season. Mammoth red clover is best adapted to northern Minnesota growing conditions.

Red clover has pubescent (hairy) upright growing stems originating from a narrow crown near the soil surface. 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 *Varietal Trials of Selected Farm Crops*, Minnesota Report 221).

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 persistence is reduced by high temperature and low moisture, but it is also intolerant of flooding. Red clover is susceptible to winter injury partially because the crown of the plant is at the soil surface and is not covered 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 4, 5 and 6). In southern Minnesota, it generally yields less and is less persistent than alfalfa, partly due to its low drought tolerance (tables 7 and 8).

Red clover produces high quality forage due to leafiness and stems which are relatively high in nutritive value (table 9). Animal performance on red clover pasture is similar to that on alfalfa (table 10). However, the long term carrying capacity and production per acre is lower for red clover than for alfalfa due to less stand persistence.

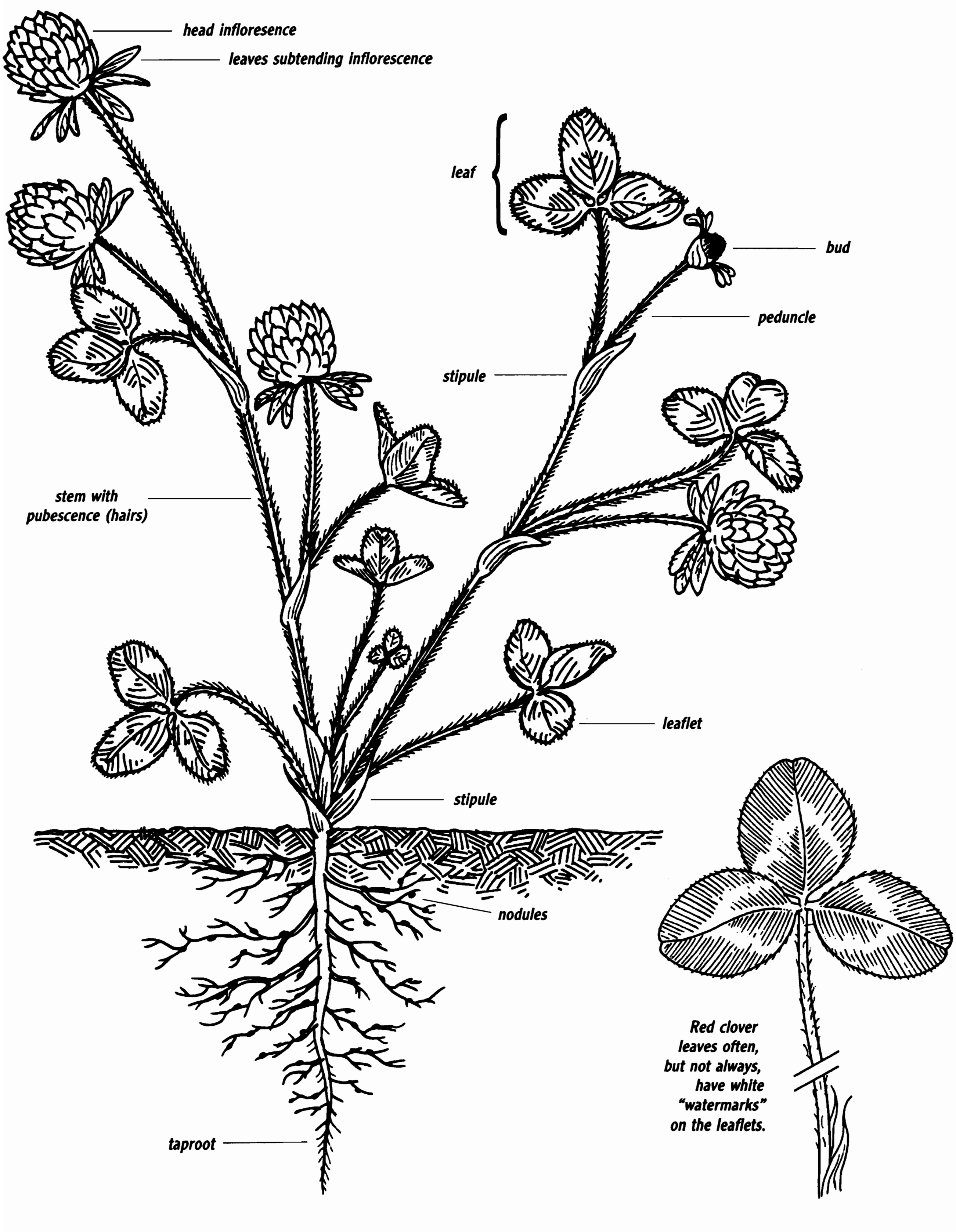
Red clover is a two- or three-cut crop that is usually harvested at early flowering (with about 25 percent of stems flowering). Allowing the crop to reach full flower (100 percent of the stems with mature flowers) will result in very low quality forage. Because red clover is high in moisture, it is sometimes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

Red clover is frequently planted 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 infected by black patch disease. This disease is caused by *Rhizoctonia leguminicola,* which produces the alkaloid slaframine, which induces salivation (Taylor, 1985).

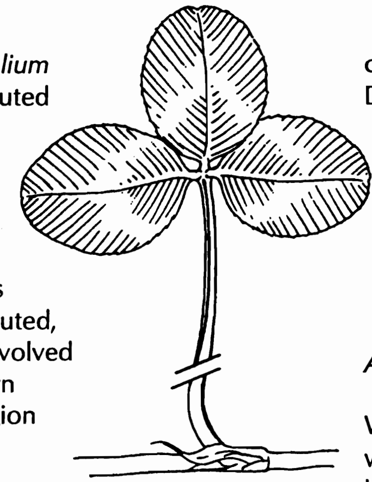
Red clover possesses good seedling vigor and is excellent for pasture renovation using sod-seeding or frost-seeding (table 11).

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 Justin et al. (1967).

Figure F. Red clover plant illustrating upright growth habit.



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. The small seed of white clover was rapidly spread by grazing livestock and other animals as deforestation occurred in the colonies.

White clover is not a major cultivated forage legume in Minnesota, because of poor persistence and low productivity (tables 5, 6, 7 and 8). 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 or hay mixtures.

As its name implies, white clover has white blossoms which are borne on long peduncles. White clover is unique among the legumes grown in Minnesota because it spreads by stolons (above-ground stems) (figure E). White clover'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 are grown in Minnesota: ladino, white Dutch (also known as intermediate clover) and wild white clover. White Dutch and wild white clovers are very prostrate. They are often found in permanent pastures and in 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 Minnesota are unnamed common types. Two named ladino clover varieties which are sometimes sold are *Merit 3,* and *Sacramento.*

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

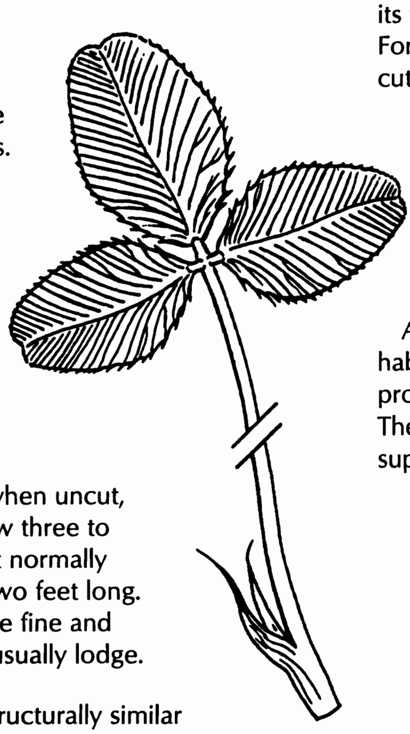
White clovers are most often used for pastures, and are often sold as components of pasture mixtures which include grasses. Recently, ladino white clover has been included as a component in wildlife mixtures being sold to feed and attract whitetail deer. White Dutch and wild white clovers often naturally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

All of the white clovers have a high forage nutritive value (table 9) 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 for white clover.

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).

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 regions it typically produces like an annual or biennial. Alsike clover is frequently used as a component of commercial pasture mixtures because of low seed cost and its adaption to unique soil conditions. There are no released varieties specifically developed in the United States; most seed is common. 'Tetra' is a tetraploid variety developed in Sweden which in Minnesota has similar yield and persistence as the common varieties.



Alsike clover has an upright growth habit like red clover, but its stems and leaves lack pubescence. Under favorable conditions, and when uncut, its stems can grow three to five feet long, but normally they are one to two feet long. Because stems are fine and weak, tall stems usually lodge.

Alsike clover is structurally similar to red clover, but with a flower more similar to white clover. The pink-white flowers of alsike are smaller than those of red clover. Its stem bears flower heads along its entire length, the oldest below and the youngest at the top of the stem. Leaves are never varigated or 'watermarked.'

ADAPTATION

Alsike clover is best adapted to moist or poorly drained soils. It usually does not persist on dry sandy soils. It will tolerate waterlogged soils and can withstand spring flooding for up to six weeks. At the other extreme, it is not tolerant of drought or high temperatures. Alsike clover will tolerate acidic soils with a pH of 5.0. In Minnesota alsike clover is best adapted to the cool, moist climate of the northern parts of the state, and to low lying moist areas in the south.

USE

Alsike clover is used for hay and pasture but its forage yield is low (tables 5, 6, 7 and 8). For hay production, usually only one or two cuts are possible, with the first spring harvest usually representing about 80 percent of the total season yield. The forage is often higher quality and leafier than forage of red clover or white clover, but alsike clover can cause bloat and photosensitization (table 9).

Alsike clover has indeterminate growth habit and if uncut continues to flower and produce seed throughout the growing season. Therefore, on adapted soils there is a large supply of seed produced for regeneration.

KURA CLOVER

Kura clover (*Trifolium ambiguum* L.) is a spreading perennial clover originating in Caucasian Russia. It is a very hardy legume and will tolerate severe continuous grazing. It is also known as Caucasian, Pellet's, or honey clover. It was first introduced into the United States in 1911, but was generally unknown until the late 1940s when it began to be used in apiaries.

Because of limited seed supplies, acceptance and use of kura clover has been restricted. In 1990, the first United States variety, 'Rhizo', was released and greater quantities of kura clover seed should be available soon.

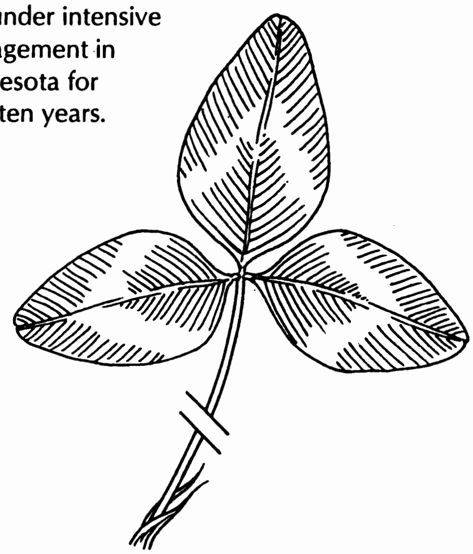
Kura clover has an extensive root and underground (rhizome) stem system. Initial regrowth in the spring consists of an upright stem containing a large white-pink flower. Following defoliation, all regrowth consists of leaves and petioles which originate from crowns. The forage is succulent and not hairy. The leaves are more pointed and usually larger than those of other clovers.

Kura clover is very persistent once established. It has poor seedling vigor, however, and is difficult to establish. Because of its low forage production during the year of establishment, seeding with a non-competitive legume like birdsfoot trefoil is recommended for weed control and to enhance yields. It is said that kura clover, "sleeps in the first year, creeps in the second year, and leaps in the third year" (G. C. Martin, *in* Fallander, 1989). Although kura clover can be grazed in the seeding year, maximum forage production may not occur until the second year after seeding.

ADAPTATION

Kura clover is adapted to a diversity of soils. It tolerates low fertility and soil acidity, wet soils, and some flooding. Although it is not high yielding under drought, it survives because of its deep root system. Its tolerance to salinity and alkalinity are not yet known.

Kura clover is extremely winter-hardy and has survived Minnesota winters when other legumes including alfalfa, birdsfoot trefoil, and red clover were killed by low and fluctuating temperatures (table 7). Stands of kura clover have remained productive under intensive management in Minnesota for over ten years.



USE

Because of its high nectar production and shallow corolla tube, kura clover is preferred by bees over other legumes. It has been used in apiaries, and has been given the common name "honey clover."

Kura clover has great potential as a pasture legume for either continuous or rotational grazing. It has excellent long term carrying capacity and gain/acre potential (table 12). With increased availability of seed and careful establishment, kura clover has potential to greatly enhance productivity of pastures in Minnesota.

Forage grazed by livestock is primarily leaves and is very high in nutritive value, but if grown in pure stands, kura clover can induce bloat in ruminants. Although it can be mechanically harvested, it's prostrate growth habit and high moisture content make cutting and drying difficult.

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 of sweetclover has declined from its peak of use in the decades between 1925 and 1950. This decline was the result of several factors: the decreased use of rotations, prevalence of cheap synthetic fertilizers, 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.

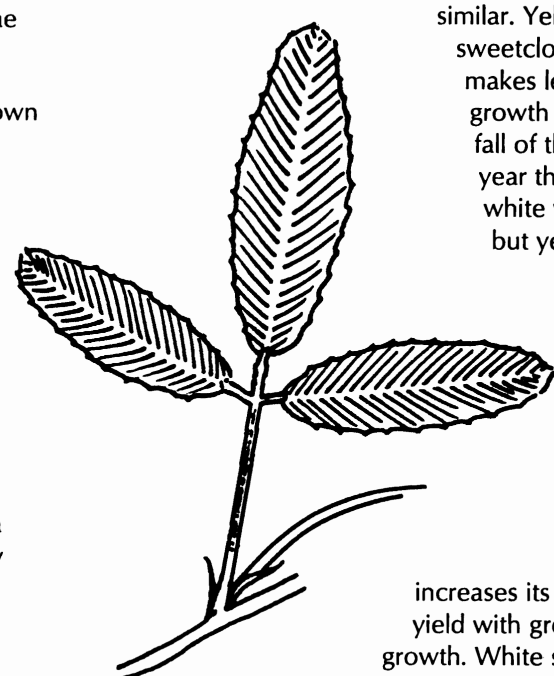
A limited amount of sweetclover is grown on government conservation program (CRP) acreage. It is also commonly found on wasteland and on roadsides, where it regenerates by self seeding. Wheeler (1950) indicated that, "sweetclover will grow anywhere, provided there is more than 17 inches of well distributed 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 emergency 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 13). Before the advent of synthetic fertilizers sweetclover was routinely used as a green manure crop in the Corn Belt.

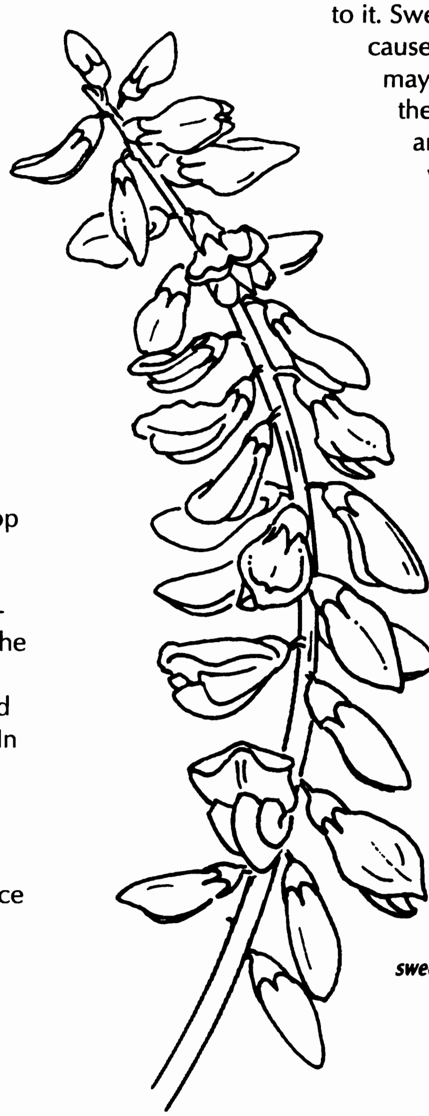
When grown for green manure, biennial sweetclover is plowed under in the spring of the second year. Plowing in the spring will kill the plants, provided plant growth is at least three inches. In contrast, with fall plowing, plants can regrow in the spring and become a weed control problem.

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 8 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.

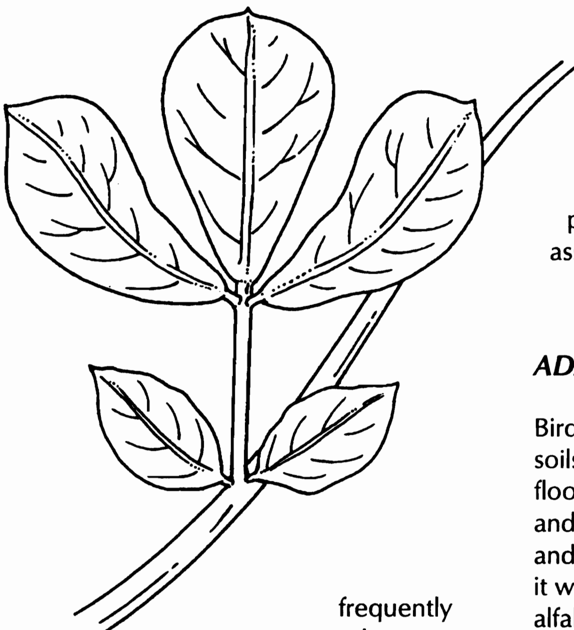
Sweetclover is low in palatability because of its coumarin content, and animals will tend to eat other vegetation before eating sweetclover. Animals can, however, adjust to it. Sweetclover also will cause bloat, scouring, and may taint milk. Despite these limitations, grazing animals can perform well on sweetclover. Grazing may begin when plants are 14 inches in height, but a minimum height of 10 inches should be maintained to allow rapid regrowth. Plants become woody and unproductive if allowed to reach bud stage before initiating grazing.



sweetclover raceme

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 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 upright (also called European) types. 'Viking' is a commonly used 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 of birdsfoot trefoil which is persistent and well adapted to Minnesota.

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 tolerant of acid soils (pH 5.0), and is moderately tolerant of high alkalinity and salinity. On acid and poorly drained soils, it will have greater yields than red clover and alfalfa (table 14).

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 intensively managed, forage yield and stands will usually persist only three or four years due to disease and winter injury.

Stand persistence can be achieved by allowing the crop to flower and set seed. Pods shatter when mature and seed is 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

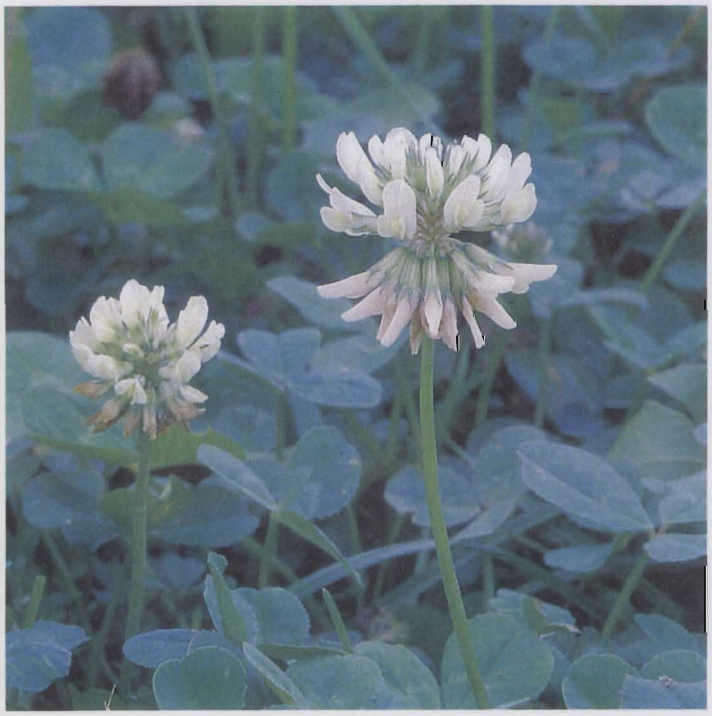
Alsike Clover

Crownvetch

Kura Clover

Birdsfoot Trefoil

White Clover



Alfalfa

Red Clover

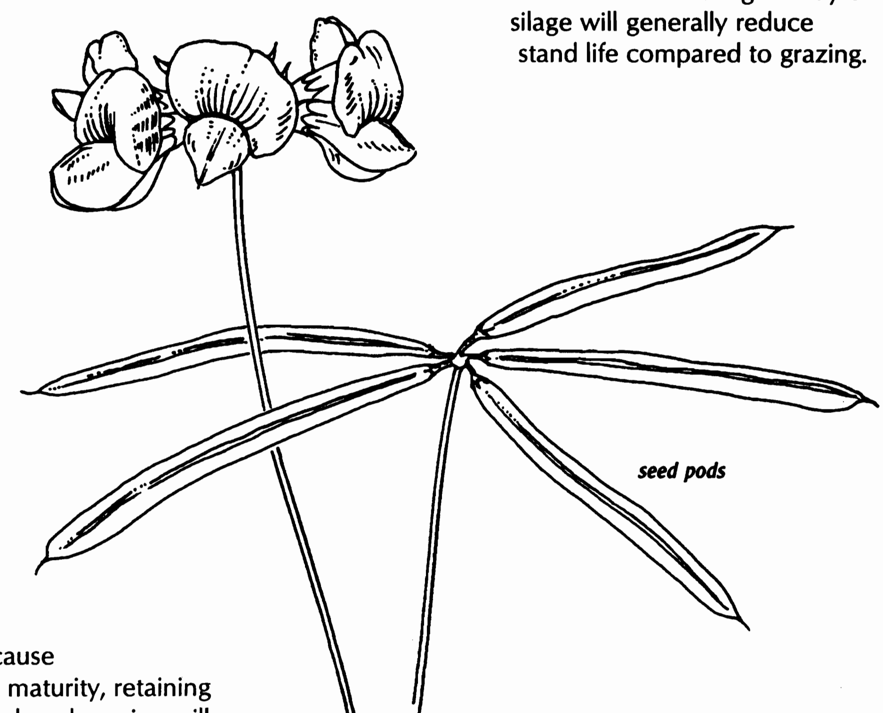
Cicer Milkvetch

microbes in the rumen ("bypassed 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, 7, 8, 10 and 15). Birdsfoot trefoil is a good legume to accumulate in place (stockpiling), delaying grazing until mid-summer or fall 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 (table 10). 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 to reduce weed invasion. For performance of birdsfoot trefoil varieties, see *Varietal Trials of Selected Farm Crops* (Minnesota Report 221).

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

CICER MILKVETCH

Cicer milkvetch (*Astragalus cicver* L.) has been evaluated and used for forage in the Great Plains and western United States. It has 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 7-9). Stands of cicer milkvetch have persisted ten years under stressful conditions in Minnesota.

The herbage of cicer milkvetch is upright during regrowth, but its stems can reach a length of four feet and will lodge with maturity. Leaves are pinnately compound with from 8 to 17 pairs of leaflets along with a single terminal leaflet. Yellow to white flowers are borne on racemes that originate in leaf axils. 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.

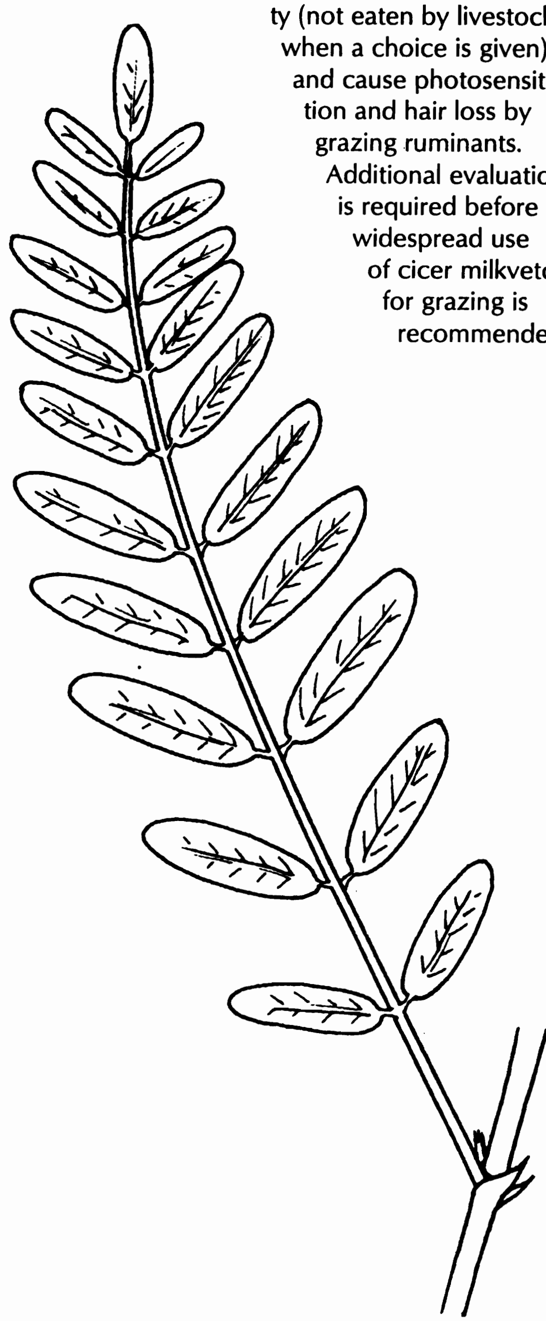
ADAPTATION

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 16). 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 10 and 15). This is due to unknown antiquality constituents which reduce palatability (not eaten by livestock when a choice is given) and cause photosensitization and hair loss by grazing ruminants. Additional evaluation is required before widespread use of cicer milkvetch for grazing is recommended.



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.

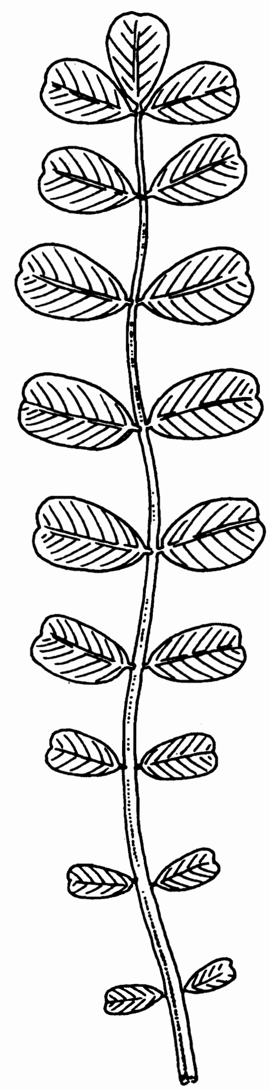
ADAPTATION

Crownvetch is tolerant of low fertility and low pH soils, but is best adapted to soils with a pH of 6 or above. It is non-bloat inducing. It 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, 7 and 8). 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 and which reduce its palatability to grazing animals.



SAINFOIN

Sainfoin (*Onobrychis viciifolia*) has been cultivated in parts of Europe and Asia for over 400 years (Smoliak and Bjorge, 1983). It is a perennial legume with good drought and cold tolerance. It grows to a height of three feet. It is best adapted to dry, neutral pH soils.

Sainfoin is intolerant of soil acidity and flooding. It has poor persistence under irrigation and in high rainfall areas due to disease. Sainfoin also does not tolerate frequent defoliation. When used for pasture or hay, it should be allowed to recover to early bloom before harvesting. In Minnesota, it is a one- or two-cut crop with low forage yield potential. Sainfoin does not cause bloat in grazing animals.

ALFALFA

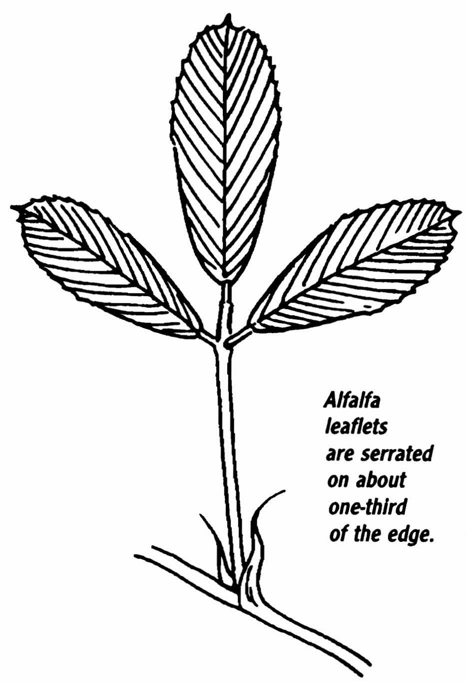
Alfalfa (*Medicago sativa* L.) is the most important perennial forage legume grown in the United States. It is, therefore, the legume against which all others are measured, and it is included in this publication for the purpose of comparison.

Alfalfa is also the most important perennial forage legume grown in Minnesota and other states in the north central region.

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 Iraq, Iran, and Afghanistan. It was described as a source of animal feed as early as 490 B.C. by the Roman writers Pliny and Strabo. It has been dispersed throughout the word by explorers, armies, and colonists.

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

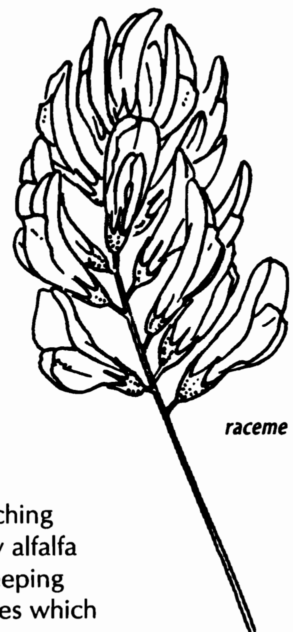


Alfalfa leaflets are serrated on about one-third of the edge.

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, over 100 alfalfa varieties are marketed in Minnesota

(See *Varietal Trials of Selected Farm Crops,* Minnesota Report 221).

Most commercial alfalfa varieties have a deep tap root and upright herbage which originates from a large crown. Leaflets are serrated on from 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. 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.



raceme

ADAPTATION

Alfalfa requires soil pH of 6.5-7.0 and high levels of soil nutrients for good persistence and yield (table 14). Potassium is especially critical for high yields and persistence. Alfalfa is intolerant of flooding and water logged soils. Adapted varieties of alfalfa can survive temperatures as low as 0° F and above 120° F. Alfalfa becomes dormant during severe drought and resumes growth when moisture becomes favorable.

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 9), it is often a key component of ruminant rations. It produces greater yields of forage dry matter and protein per acre than any other forage legume under good growing conditions (tables 6, 7 and 8).

Regional and local growing conditions and goals of the producer 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. A dairy producer in southern Minnesota who routinely four-harvests alfalfa at bud stage sacrifices dry matter or nutrient yield and stand persistence for excellent quality forage and value as feed and replacement for high-cost energy and protein supplements. The increased forage quality from a four-cut schedule can result in significantly more milk per acre than a three-cut schedule (Undersander et al., 1991).

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

When alfalfa is grazed it results in good gains and carrying capacity (tables 10 and 14). 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 Hanson et al. (1988); Undersander et al., (1991). Many alfalfa varieties are described in *Varietal Trials of Selected Farm Crops* (Minnesota Report 221).

CULTURAL PRACTICES FOR FORAGE LEGUMES

ESTABLISHMENT

Establishing small seeded legumes is more challenging than for most large seeded annual crops such as corn and soybean, or for small grains. Seedlings are fragile and develop slowly (figure G). 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 good practice 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 cheaper than named varieties. Minimum recommendations are to purchase seed which contains the following information on the seed tag:

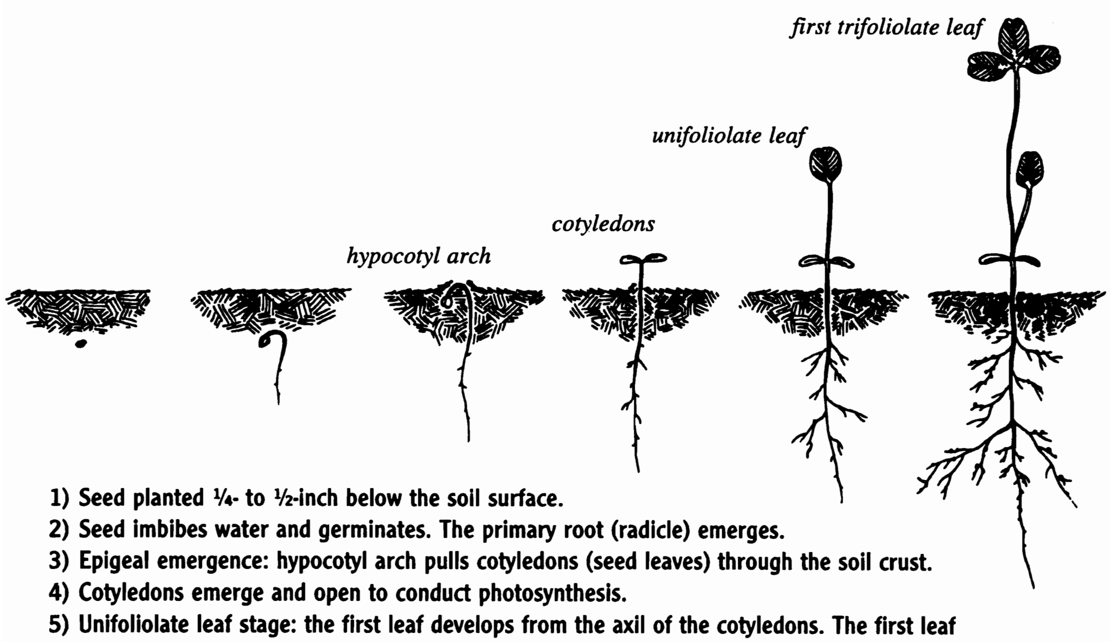
- percent germination,
- percent inert matter,
- percent other crop seed,
- percent weed seed, and
- crop species.

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

INOCULATION

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

Figure G. 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 H. A formula can be 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 %)

preinoculated 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, sainfoin, 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, alternate 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 should 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 which insures good soil-seed contact and shallow seed placement are 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 will enhance 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 seeded no deeper than ¼-inch. Other legumes should be seeded from ¼- to ½-inch deep. Test your planter and determine the depth of seeding. Seeds sown either on the soil surface or greater than ½-inch deep 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, 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 17. With rough, not-firm seedbeds, the use of higher seeding rates can provide some advantages. More seeds develop into seedlings with the increased rates, however, 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.

Table 17. Seeding rates (pounds per acre) and seed characteristics of forage legumes.

	Seeding Rate			
Legume	Pure Stand [a]	Grass mixture [a]	Seeds/ lb	Seeds/ sq.ft [b]
Red clover	10	7	275,000	63
White clover	3	1	800,000	55
Alsike clover	5	2	700,000	64
Sweetclover	10	3	260,000	60
Kura clover	5	4	800,000	91
Birdsfoot trefoil	8	5	375,000	69
Cicer milkvetch	12	5	130,000	35
Crownvetch	15	—	110,000	38
Sainfoin	20	15	30,000	14
Alfalfa	12	7	220,000	60

[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.

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 18. 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.

TIME OF ESTABLISHMENT

In the spring, seeding should occur from April 15 to June 1 in the south and from May 1 to June 15 in the north. In summer, seeding should be done from August 1 to August 15 in the south and from July 15 to August 1 in the North. Early spring seedings take advantage of adequate moisture and cool temperatures. Summer seedings generally have less weed competition than spring seedings, but moisture may be limiting.

Most legumes seedlings require three trifoliolate leaves to develop to survive the winter. Seeding beyond recommended August dates may result in plant winter injury.

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

Table 18. Hay, silage and pasture mixture seeding rates (pounds per acre) suggested for Minnesota.

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

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.

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.

WEED CONTROL

Spring seedings are more likely to have 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 *Cultural & Chemical Weed Control in Field Crops,* Minnesota Extension Bulletin AG-BU-3157).

FROST SEEDING

Frost seeding involves spreading seed on the soil in late fall or winter. The freezing and thawing action of the soil or animal trampling bury the seed. If frost seeding is planned for permanent pastures, heavy grazing prior to seeding will both enhance soil-seed contact and suppress existing perennial grasses. This will consequently improve legume establishment.

Following seeding, pastures should be grazed when grasses form a canopy and shade the legume seedlings. Post seeding grazing should be accomplished in a short time period with a high stocking rate to avoid excess trampling and animal selection of the succulent legume seedlings. Yearly seeding of pastures with a low cost legume like red clover, white clover, or alsike clover will develop a legume seed bank and assure adequate legume populations in pastures.

Legumes can also be established in permanent pastures by light disking in early spring to loosen the soil, followed by broadcast seeding of legumes. As with frost seeding, this method is most cost effective with red clover, white clover, or alsike clover.

SOD-SEEDING

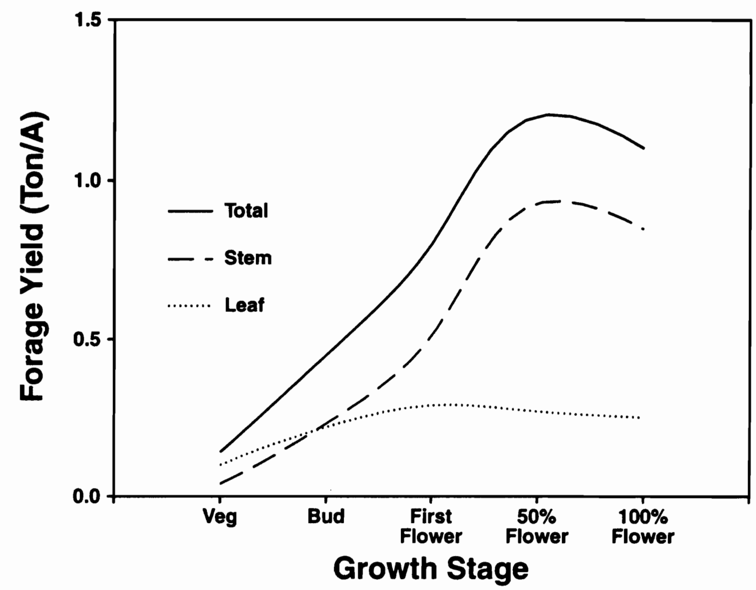
Sod-seeding using specialized equipment is an alternative method of introducing forage legumes into pastures. In addition to monitoring and adjusting soil fertility, important procedures include controlling perennial weeds, and grazing before and after seeding to suppress existing grasses (table 11). More information on sod-seeding can be obtained in Agronomy fact sheet 34-1978, University of Minnesota Extension Service.

HAY AND SILAGE HARVEST MANAGEMENT

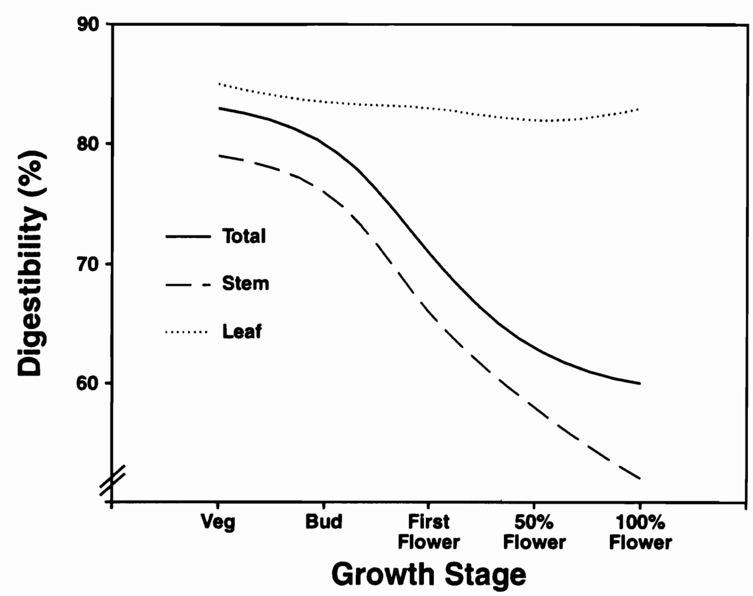
While yield increases with increased maturity, the forage quality of many legumes decreases (figure I). Therefore, cutting schedules with more frequent harvests (e.g. a four-cut schedule) usually have greater nutrient concentrations but lower yields than schedules with less frequent harvests (e.g., two- or three-cut schedules) (tables 6, 7, 8 and 9). 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.

Figure I. The relationship between maturity of a representative legume (birdsfoot trefoil) to its forage yield and digestibility.

(a) 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 greater stem proportion.



(b) 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. *Agron. J.* 78:704-710.

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 clover, kura clover and cicer milkvetch, which have stems and leaf area escaping defoliation can tolerate more frequent cutting.

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 forage (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.

In contrast, rotational grazing involves rotating grazing animals among paddocks, and controlling the animals' 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

Initiation of grazing. Erect legumes like alfalfa, birdsfoot trefoil, and red clover should be grazed when vegetative at 8 to10 inches in height. Short legumes like white clover and kura clover should be grazed when 4 to 6 inches high.

Following grazing, most grasses and legumes will begin their regrowth within a week. Short grazing periods, ½ to 3 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 harvest. Legume grazing is usually initiated at vegetative stages.

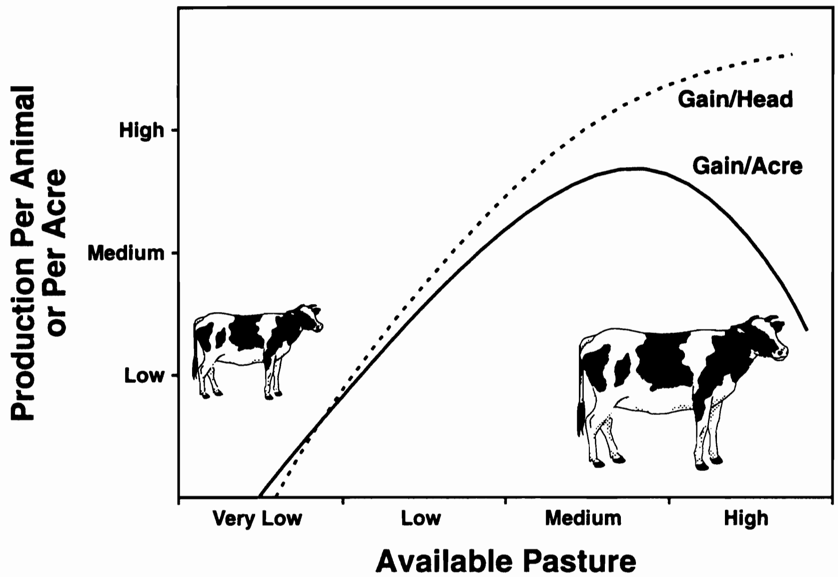
HEIGHT OF GRAZING

The height of forage after being 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 2 and 4 inches of stubble height. Increasing the stubble height will allow more rapid regrowth and will enhance persistence.

Since forage at the top of plants is usually the highest quality, 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 this type of grazing management. It would allow those animals with the higher energy needs to have first access to pastures before ewes.

Figure J. 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.



STOCKING RATE

Your stocking rate will greatly influence yield per acre and per head (figure J). 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.

APPENDIX A: TABLES 4 THROUGH 16

USING LEAST SIGNIFICANT DIFERENCES

For tables 4 through 16, 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 4 below, Marathon yielded 2.36 tons per acre with three-cuts in 1990, while Arlington only yielded 1.54 tons per acre. The difference of 0.82 tons per acre exceeds the LSD value of 0.45. We can therefore say with some confidence that Marathon had greater yields that Arlington.

Table 4. 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	89
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 5. Red clover, ladino clover and alsike clover forage yields (tons per acre) and stands (percent) at Grand Rapids, Minnesota.[a]

	Forage yield			Stands
Legume	1989	1990	2-yr total	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 6. Effect of cutting schedules on forage yield (tons per acre) and final stands (percent) of perennial legumes at Grand Rapids, Minnesota.

		Forage yield			Stands[c]	
Schedule[a]	Legume[b]	1987	1988	2-yr total	1987	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/yr: 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 7. Effect of cutting schedules on forage yield (ton per acre) and final stands (percent) of perennial legumes at Rosemount, Minnesota.

		Forage Yield				
Cut/year [a]	Legume [b]	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/yr: 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 8. Effect of cutting schedules on forage yield (tons per acre) and final stands (percent) of perennial forage legumes at Lamberton, Minnesota.

		Forage Yield				
Cut/year [a]	**Legume [b]**	**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/yr: 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 9. 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.

		Percent dry weight		
Cuts [a]	Legume [b]	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/yr: 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 10. 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. *Crop Sci.* 30:860-866.

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

Table 11. Seeding year yield (tons per acre) of red clover and alfalfa sod-seeded at several rates (pounds per acre) into a smooth brome-grass 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 suppression were obtained by applying 1.5 and 0.5 lbs/acre of glyphosate 24 hours before inter-seeding of legumes.

Table 12. Average total season leafiness and crude protein, digestibility, and neutral detergent fiber concentration of birdsfoot trefoil and kura clover forage, and sheep 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. 1991. *Agron. J.* 84:176-180.

[b] Values are averaged for 4 production years.

[c] Statistically significant differences between species.

Table 13. 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 14. Forage yield (tons per acre) of varieties of birdsfoot trefoil, red clover and alfalfa seeded at Beaver Bay, Minnesota. [a]

Legume	Forage yield			Percent of alfalfa yield
	1984	1985	2-yr total	
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	—	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 15. 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 16. Total season forage yield and average forage quality of perennial legumes when grown with irrigation or drought on a sandy soil at Becker, Minnesota. [a]

	Forage tons/acre		Forage ADF %		Forage CP %	
Legume	Irrigated	Drought	Irrigated	Drought	Irrigated	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		1.7		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.

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