FORAGE LEGUMES

Clovers, Birdsfoot Trefoil, Cicer Milkvetch, Crownvetch and Alfalfa




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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 third edition is completely online and features new data in addition to preserving information from previous editions.

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 italics. 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: 2018

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INTRODUCTION

Forage legumes belong to the legume or bean family (Fabaceae or Leguminosae). Members of this large family (more than 19,000 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 field 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.

Each legume has a unique binomial Latin name: the genus and species. Each unique plant is called a species. Both name are always italicized and the genus is capitalized. For example, white clover is *Trifolium repens* L. with “L” being an abbreviation for Linnaeus, a Swedish scientist who first named white clover. Therefore, sometimes in this text, we will describe a specific legume as a species.

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 orchardgrass, tall fescue, meadow fescue, and Kentucky bluegrass.

Legumes are also well known to improve soil health, and their use for that extends far back in history. They enhance soil health 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. In addition, perennial forage legumes like alfalfa and red clover that provide soil cover during the winter can provide control of soil erosion.

Early Roman writers on agriculture, such as Pliny and Virgil, recognized the value of using legumes like peas, 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 and associated field activities, thus saving producers time and money.

NITROGEN FIXATION

Many important food plants like corn, wheat, and oat require nitrogen fertilization for growth and yield. In contrast, 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 (N2, 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 be 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. When legumes are used to provide nitrogen for subsequent crops, they are often referred to as a "green manure" crop. On many Midwestern farms that use crop rotations, a green manure crop – such as a productive alfalfa stand three or more years old – can usually provide all the nitrogen requirements for a subsequent 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 2 ½ percent nitrogen. That is why green manure systems usually allow a significant amount of herbage to accumulate in the fall before incorporation.

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, structural composition, precipitation patterns, and the legume composition of the stand. Legume nitrogen is transferred by root exudation, decomposition of

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

(a) Birdsfoot trefoil

(b) Red clover

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. 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 legumes covered in this document 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 1. Quantities of nitrogen fixed by various legumes.

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
Red clover	149-168
Red clover	60-200
Soybean	20-200
Sub clover	52-163
Sweetclover	120
White clover	115-180

Source: Heichel (1987); Date and Brockwell (1978); Sequin, et al. (2000).

Table 2. Characteristics of forage legumes. [a]

Legume	Tolerance to: Heat/ drought	Wet	Winter injury	Frequent cutting/ grazing	Soil salinity	Soil acidity	Soil alkalinity	Seeding 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	G	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	Nemotodes
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

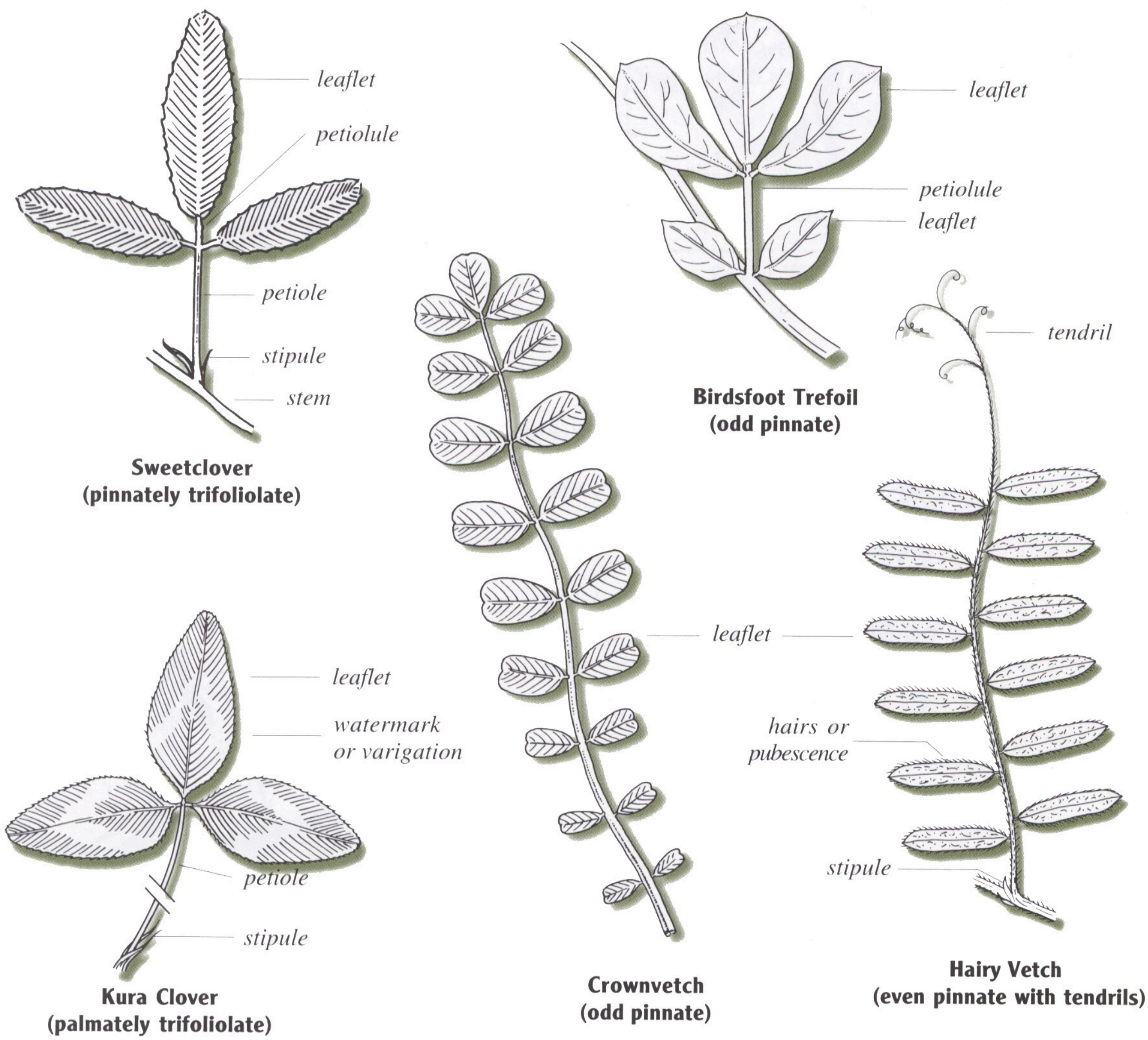
LEAVES

Leaf traits can be used to identify individual legume species. Legume leaves are usually 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. Some legumes have 10 or more leaflets.

Four arrangements, or organizations, of leaflets occur in 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. Legumes that have palmately trifoliolate leaves are called “true clovers”.

Figure B. Legume leaves are compound (more than one leaflet/leaf) and often have large stipules. The leaves are borne on petrioles 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 including many species of native bees as well as the European honeybee. Legume flower parts are the standard (also called the banner), wings and keel (Figure C). The keel surrounds the male and female sexual parts.

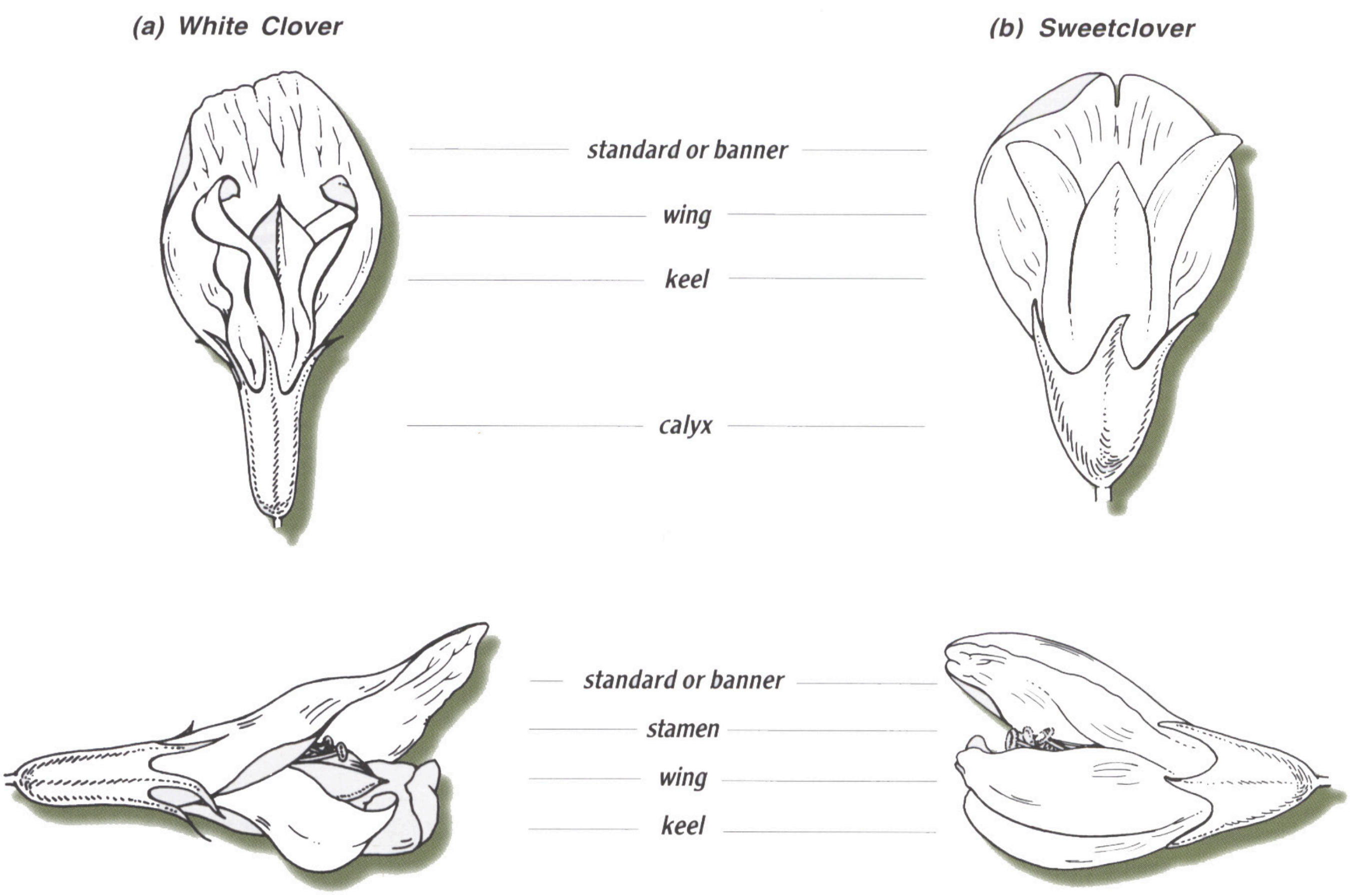
Legume flowers are arranged in groups called inflorescences (Figure D). The most common legume inflorescences are the head (in red, white, alsike and kura clover), raceme (alfalfa, sweetclover and cicer milkvetch), and umbel (birdsfoot trefoil and crownvetch). A head will typically contain many flowers while racemes and umbels contain few. After pollination, legume seeds develop in pods. The pods can contain several seeds, as in birdsfoot trefoil and alfalfa, or only one seed, as in kura clover and sweetclover. When pods are dried, they can shatter and seed is dispersed.

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 flowers 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).

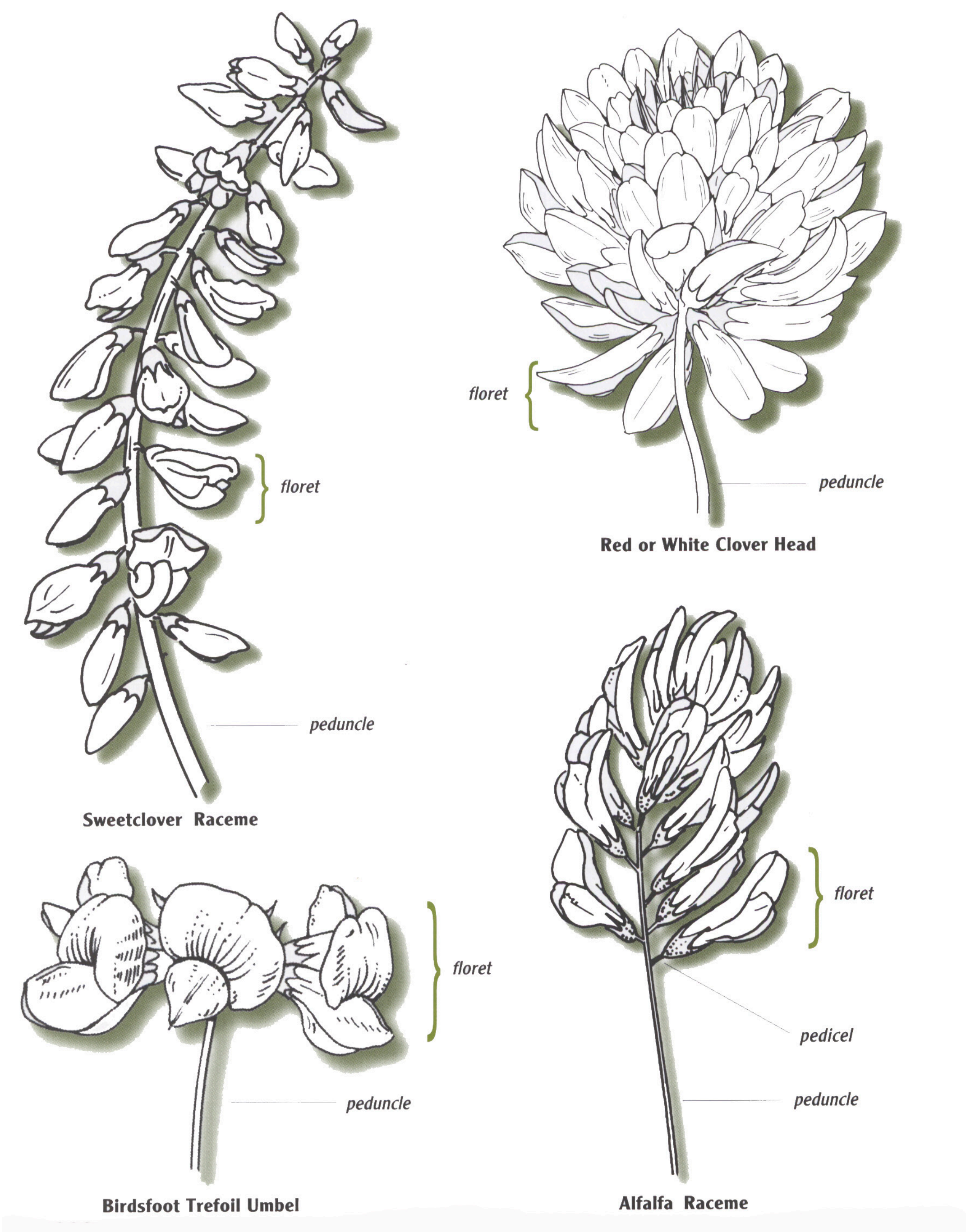
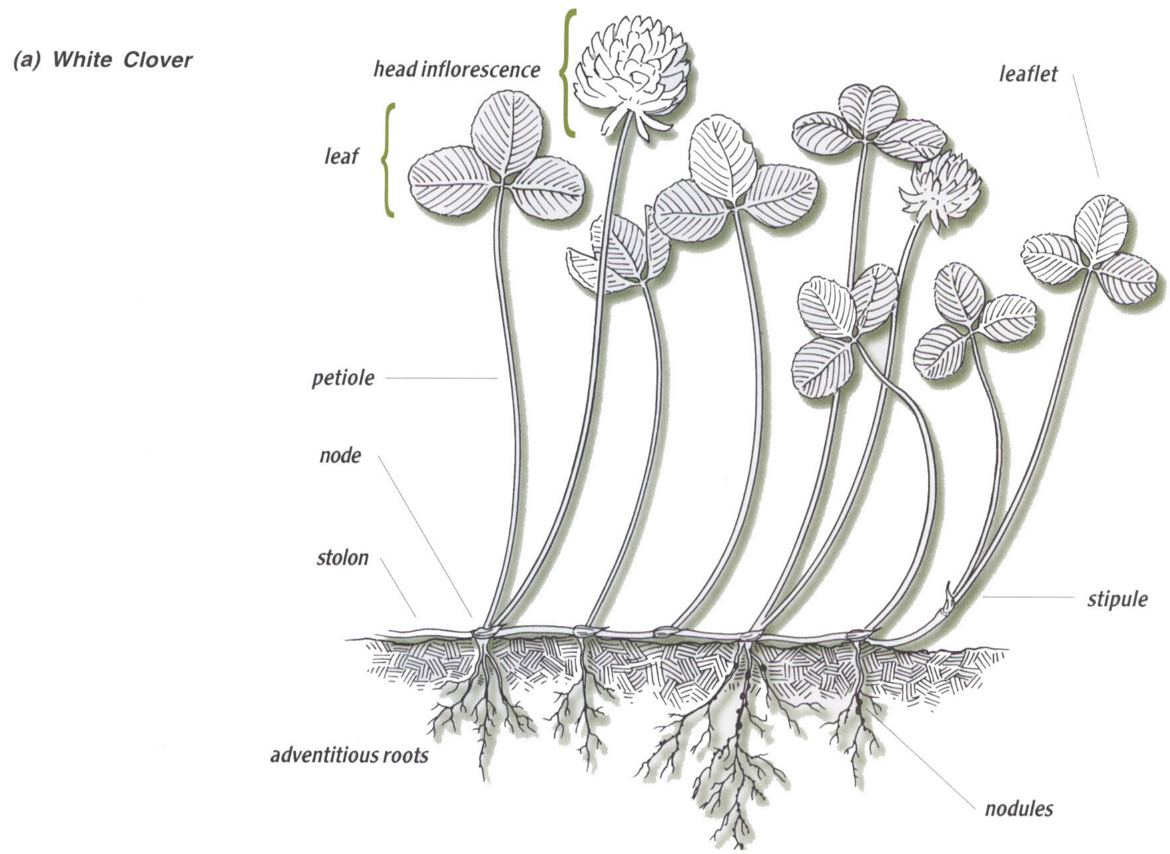
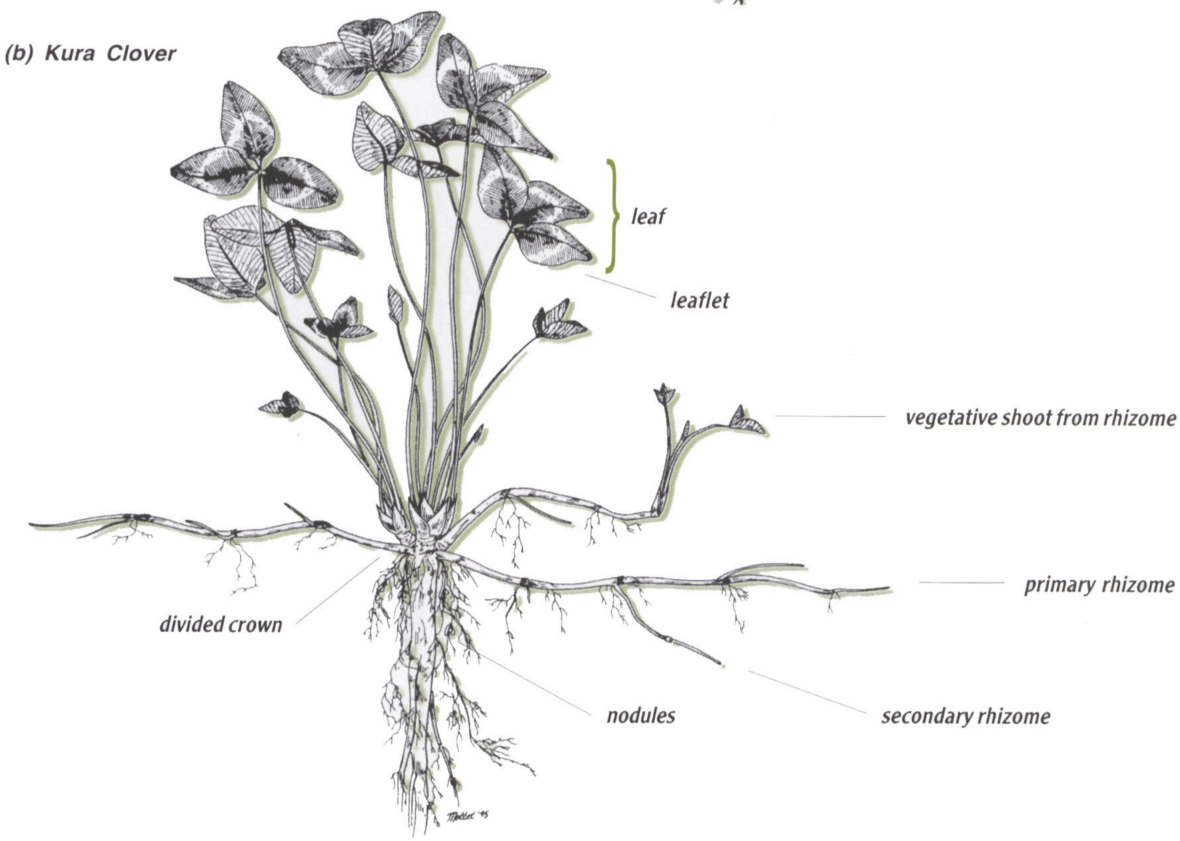


Figure E. White clover (a) stolons illustrate vegetative spreading with the development of adventitious rooting from nodes in contract with soil. Kura clover (b) spreads vegetatively with rhizomes.

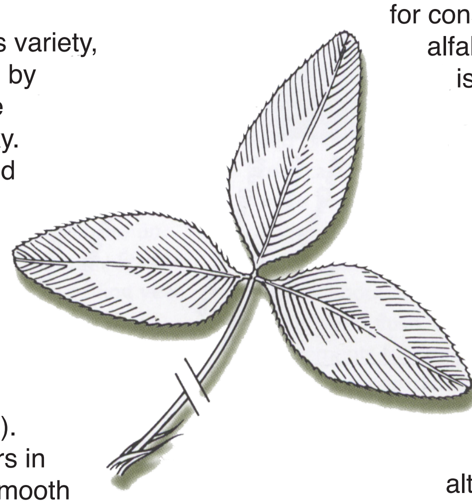




KURA CLOVER

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 1940's 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, MN and for 12 years in mixture with different grasses in Arlington, WI. Newer varieties include 'Everlast', 'Endura', and 'Cossack' (DeHaan et al., 2001; Table 4). 'Endura' has survived 22 years in mixture with tall fescue and smooth bromegrass in rotationally-grazed pastures near Lancaster, WI.



Kura clover has a deep branching taproot and has rhizomes (horizontal below ground 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; ¼ 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 below ground structures is only minimally affected.

Kura clover is very winter-hardy. It goes dormant in the early fall in response to short day-length and low temperatures. It is very resistant to injury due to freezing and thawing, persisting over 20 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.

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

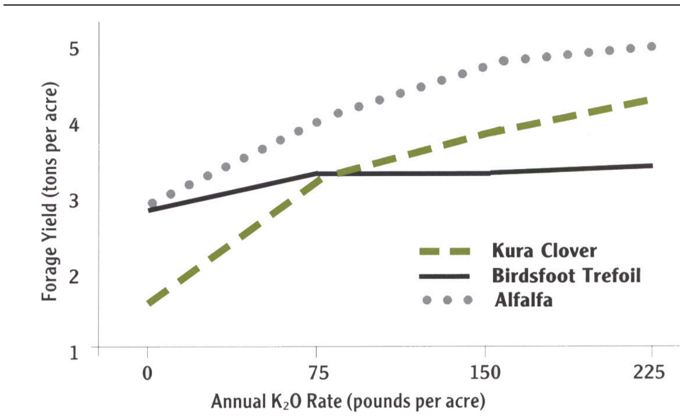
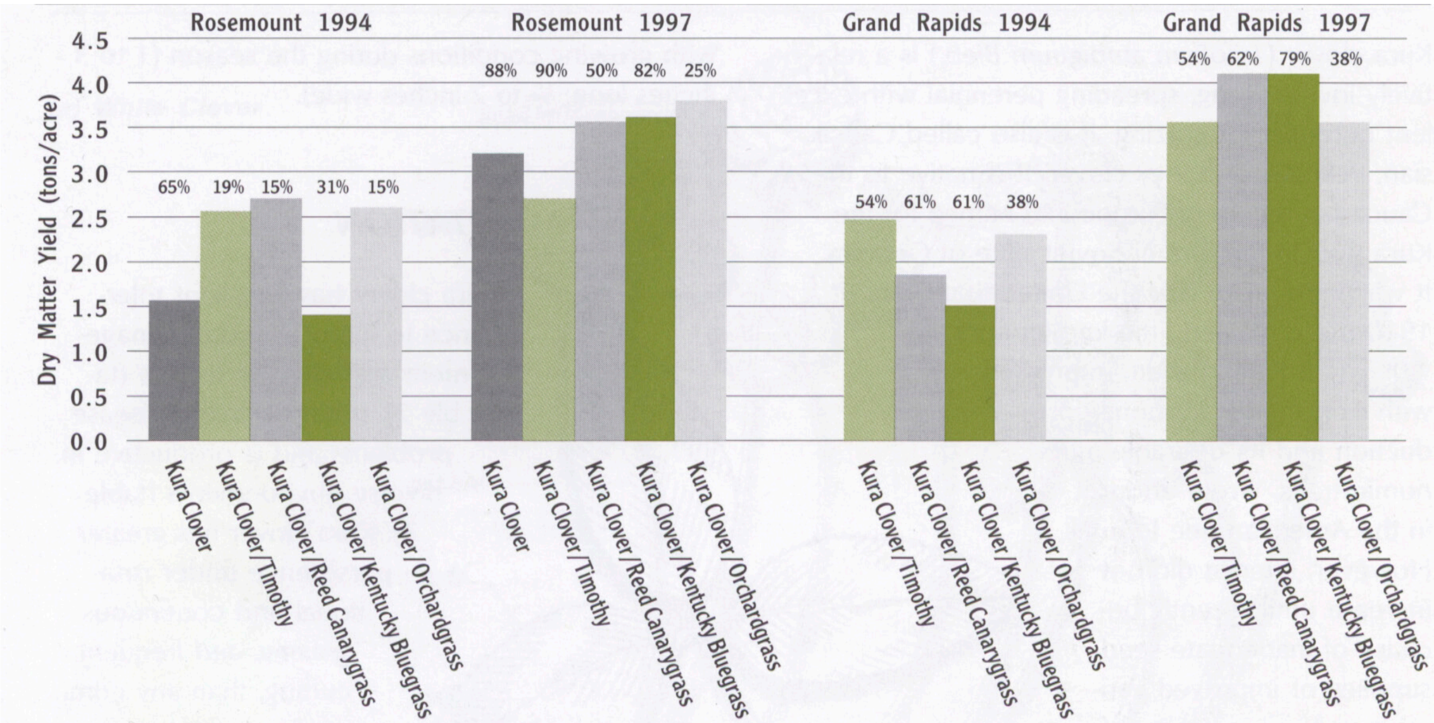


Figure G. Yields of mixtures of kura clover with perennial grasses at Rosemount and Grand Rapids, Minnesota. Percentage data above each bar is the kura clover proportion of the mixture.



Kura clover is 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 9). Its forage quality often exceeds the quality of other commonly grown legumes. 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 10-12). 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). 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. Greatest kura clover establishment yields can be achieved by using a herbicide for weed control in the seeding year (Table 13). Companion crops that are planted to reduce soil erosion should be harvested for forage at vegetative stages to reduce competition. Kura clover has also been successfully seeded into pastures with no-till strategies, provided that existing grasses are suppressed with herbicides such as glyphosate (Table 14) (Cuomo et al., 2001; Mourino et al., 2003; Laberge et al., 2005). No-till approaches reduce soil erosion and can reduce annual weed pressure.

Kura clover has been successfully established by transplanting portions of the underground rhizomes (figure E; Sheaffer et al., 2008). Transplanted rhizomes with one or more nodes can form new roots and crowns and spread within a field if soil moisture and fertility are adequate (Table 15). Large fields have been established using a potato digger to extract rhizomes and crowns followed by spreading of the plant material onto a new tilled field using a manure spreader and incorporating by disking (Baker, 2012).

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 16). 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. However, when soybean was no-till seeded into a suppressed kura clover living mulch, soybean seeds yields were reduced compared to when soybean was seeded into kura clover killed by tillage (Pedersen et al., 2009).

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, rogueing 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.

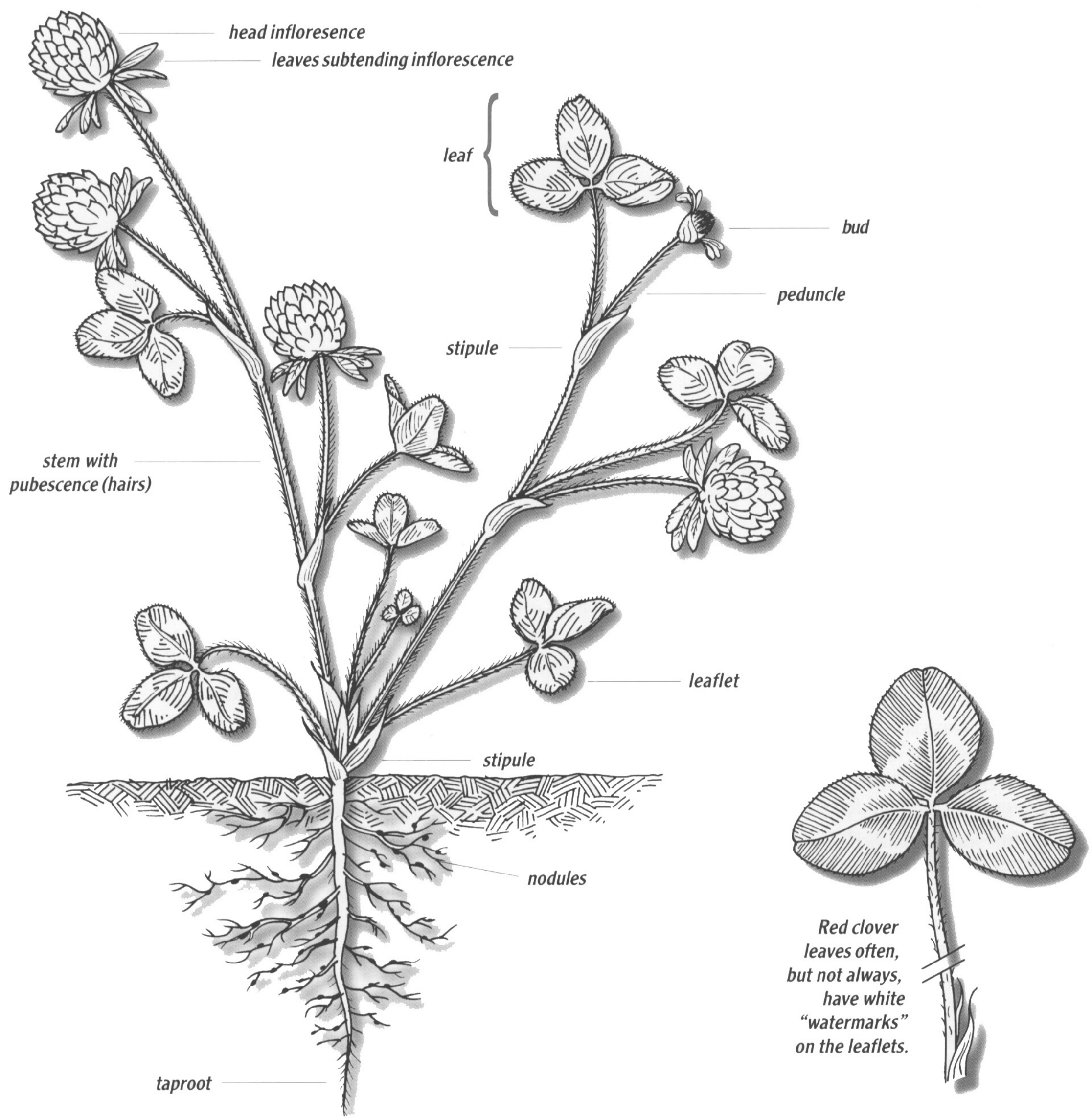
RED CLOVER

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 used in regions where soil pH is less than optimum for alfalfa and where forage yield goals are less.

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 flowering than medium red clover and produces only one crop of hay per season.

Red clover has pubescent (hairy) upright growing stems that originate from a narrow crown near the soil surface (Figure H). The plant has a taproot with many side

Figure H. Red clover plant illustrating upright growth habit.



branches, but its roots do not penetrate the soil to the depth of sweetclover, kura clover, 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. New varieties are available but all can have their stand life shortened by winter injury (Table 17 and 18).

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. 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. At northern sites such as Grand Rapids, MN under 2-cut harvest management, red clover will have similar yields as alfalfa but with more intensive cutting schedules, its yield will be less (Tables 19, 20 and 21).

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. In southern Minnesota, it generally yields less and is less persistent than alfalfa, partly due to its low drought tolerance (Table 7).

Red clover produces high quality forage due to leafiness and stems, which are relatively high in nutritive value (Tables 7 and 21). It also has somewhat greater undegradable protein and greater stem and fiber digestibility 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 but product per acre is less (Table 22). 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, but this apparently has not been an issue with cattle.

Red clover has excellent seedling vigor and is good for pasture renovation using sod-seeding or frost-seeding (Table 23).

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).

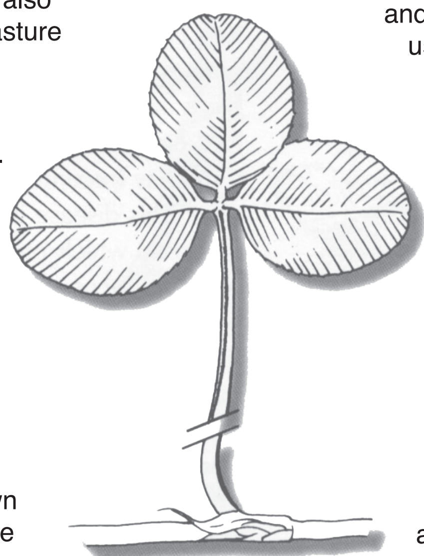
WHITE CLOVER

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 19, 20, and 21). 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). Its 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 that 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 24).

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 (Table 3).

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 that 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 that 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', were released by the Minnesota Agricultural Experiment Station but are no longer produced.

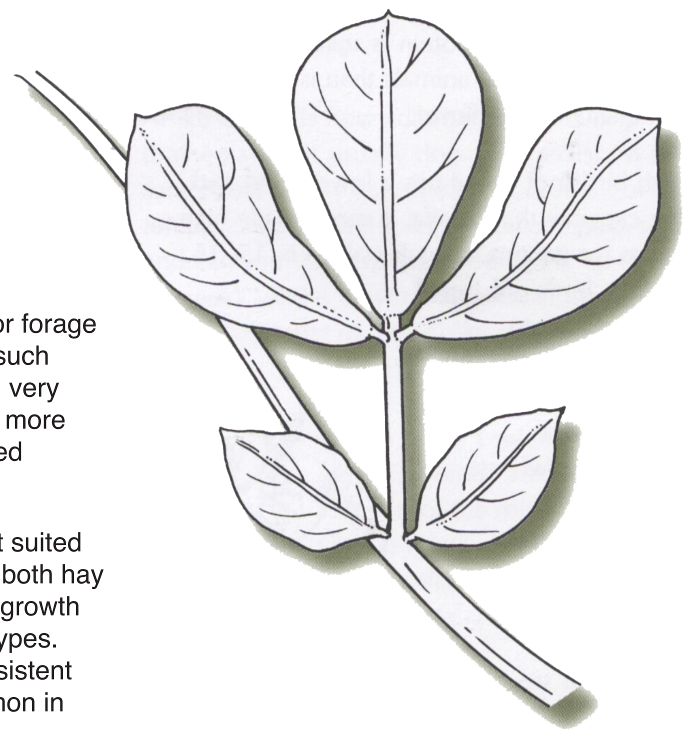
Birdsfoot trefoil has very small seeds and poor seedling vigor. Care must be taken to assure its establishment.

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 25).

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

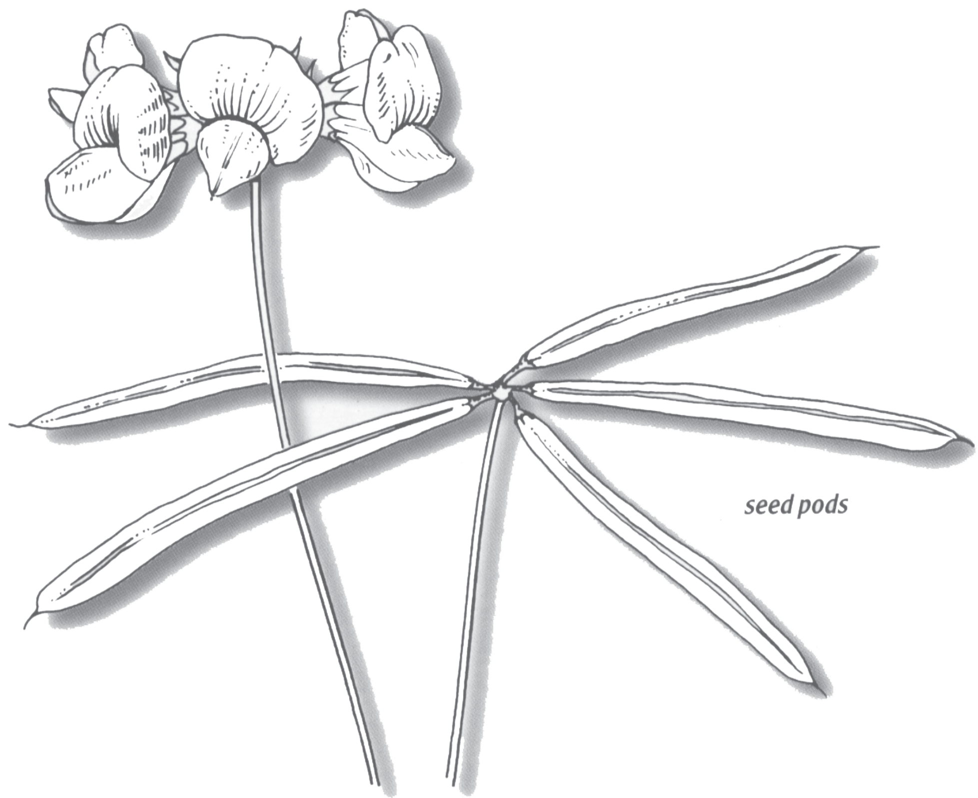
Birdsfoot trefoil should be considered primarily for pasture systems where animals can graze the forage. Birdsfoot trefoil contains tannins, which prevent legume bloat in grazing animals. In addition, because the protein in birdsfoot trefoil is less readily broken down by microbes in the rumen ("bypass 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 22 and 26). 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. Hay harvests should occur at early flowering. Mechanical harvesting at 1-3 inch cutting heights 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. Yields for a recent trial at Rosemount evaluating older varieties and experimental entries are shown in Table 27.

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).

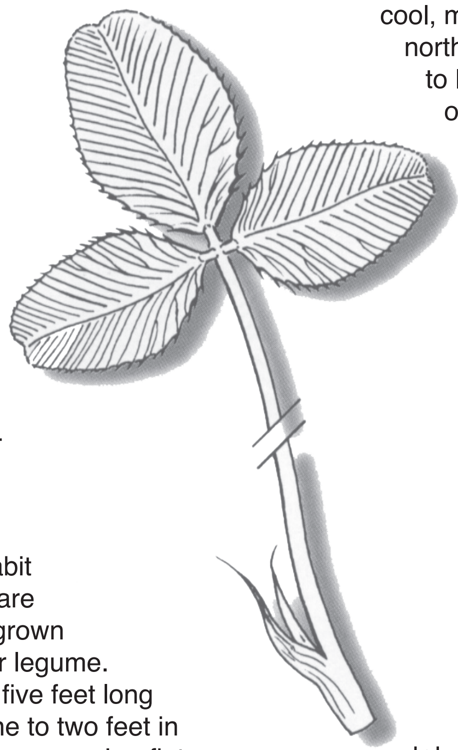


ALSIKE CLOVER

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 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 variegated 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. 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 21). Alsike clover can cause bloat and photosensitization therefore it is best to grow in a mixture with grass.

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 conservation reserve 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."

The name sweet clover is derived from the sweet odor that arises when leaves are crushed. 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.

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.

Sweetclover plants are tall and grow to heights of two to four feet, and have a thick, coarse stem. They produce large quantities of seed that shatters on maturity leading to natural reseeding. Sweetclover leaves are pinnately compound with serrations around the entire leaf edge.

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.). Over time, a number of sweet clover varieties have been released but because of limited demand and on-farm seed production variety integrity is often lost and seed of specific varieties may not be available (Table 28; Meyer, 2005). Most sweet clover that is found on the landscape usually contains about 2 percent coumarin, but some varieties with lower levels on coumarin have been marketed. 'Denta' is a low coumarin variety developed in Wisconsin.

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

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

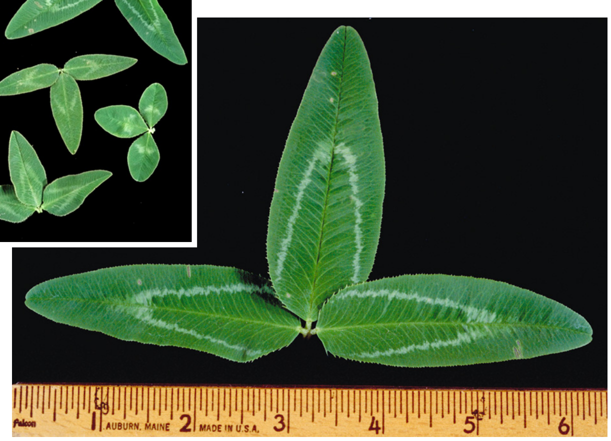
Alsike Clover

Alfalfa

Birdsfoot Trefoil

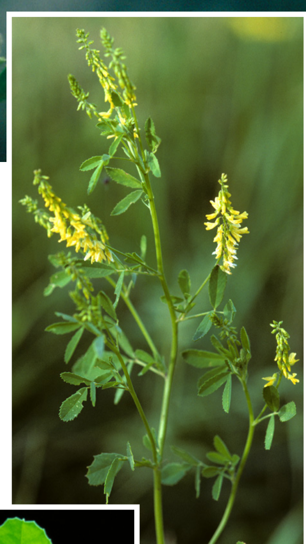
Crownvetch

Cicer Milkvetch



Kura Clover

White Clover



White and Yellow Sweetclover

Red Clover

forage but produces less root biomass than the biennial sweetclovers.

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 29). Before the advent of synthetic fertilizers, sweetclover was routinely used as a green manure crop in the Corn Belt.

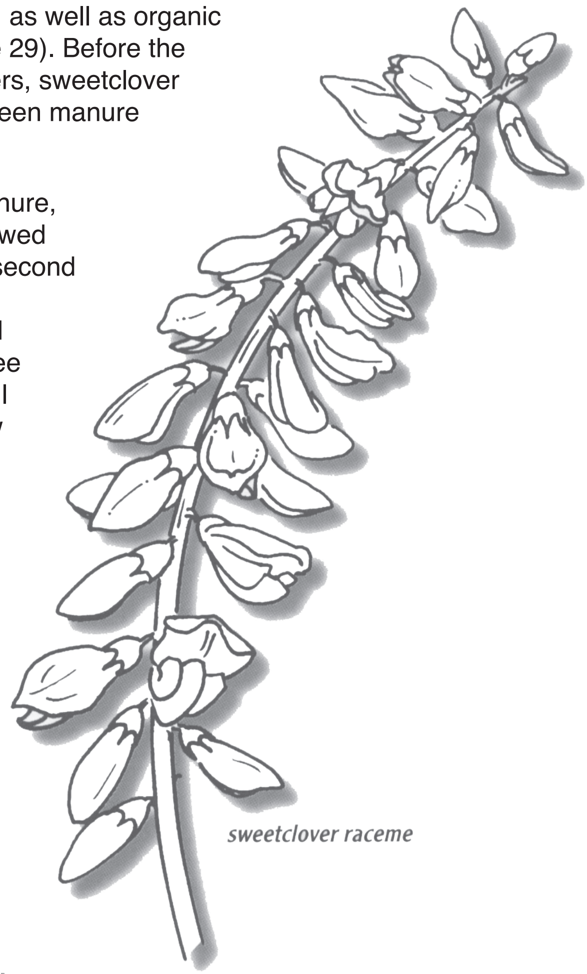
When grown for green manure, biennial sweetclover is plowed under in the spring of the second year. Plowing in the spring will kill the plants, provided plant growth is at least three inches. In contrast, with fall plowing, plants can regrow in the spring and become weedy.

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 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.



sweetclover raceme

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 vetchlike 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.

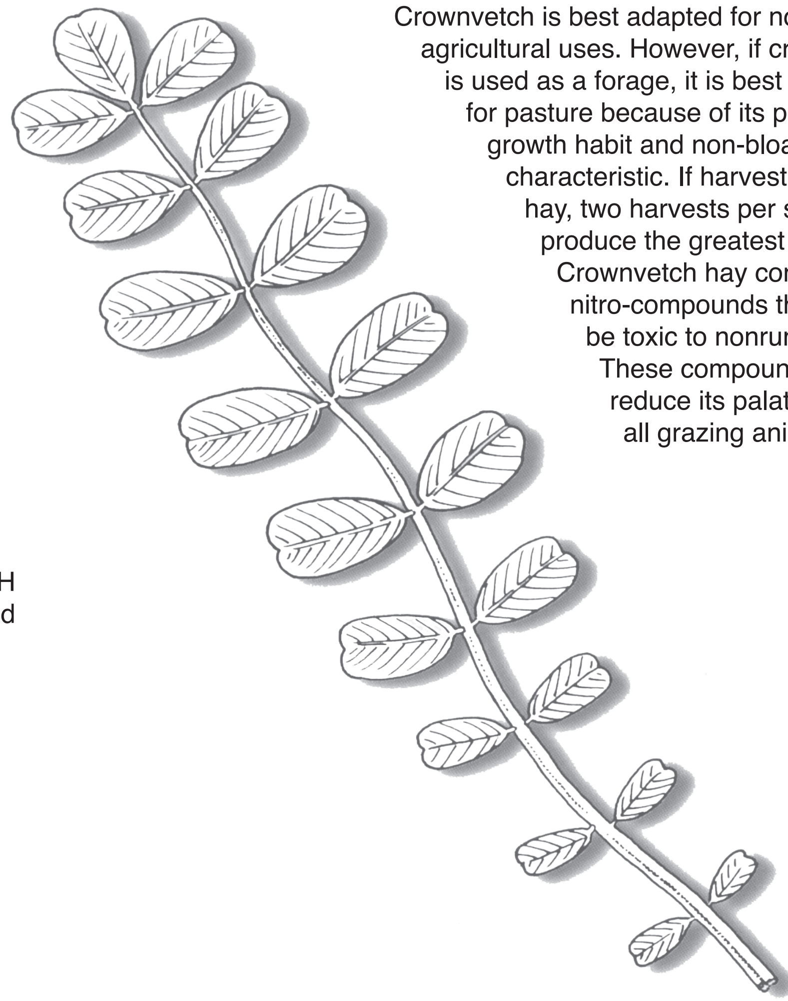
ADAPTATION

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

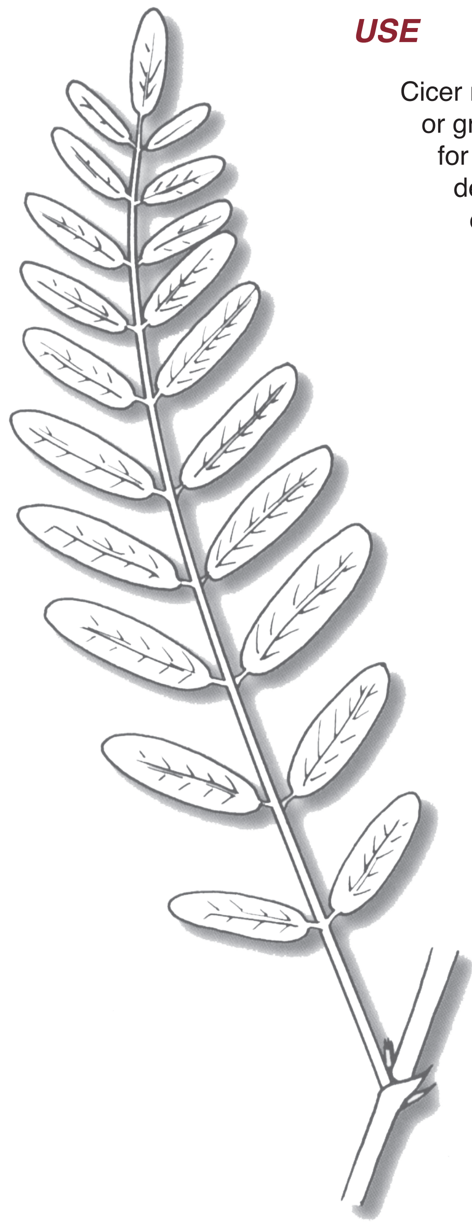
Cicer milkvetch (*Astragalus cicver* L.) has been evaluated and used for forage in the Great Plains and western United States. It has, however, only been evaluated in a limited number of trials in Minnesota.

Cicer milkvetch is a vigorous, persistent, high yielding legume that spreads by rhizomes and has a deep root system. 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 bladder like 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.

University of Minnesota researchers developed a new variety "HiPal" that has improved palatability compared to other varieties. However, that seed is no longer available.



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.

ALFALFA

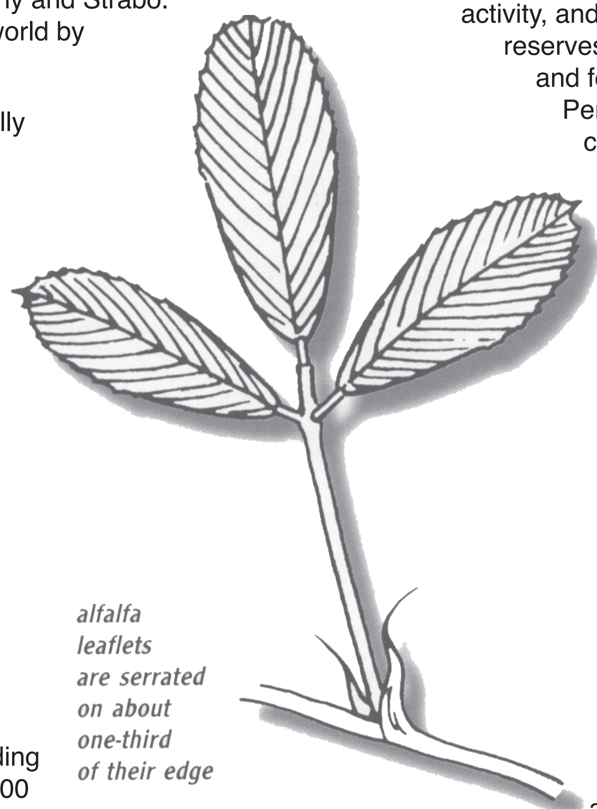
Alfalfa (*Medicago sativa* L.) is the most important and most widely planted perennial forage legume grown in the north central region and across the United States. It is, therefore, the legume against which all others are measured. Alfalfa is included in this publication primarily for the purpose of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



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

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 variegated 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. 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 animal. 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, very dormant and winter-hardy varieties can withstand temperatures as low as -5°F in the fall. 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 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. Varieties should be selected with a winter survivability rating of 2 and a fall dormancy of 4 for least risk of winter-injury. Information on winter survivability (rated on a scale of 1 (most) to 6 (least) is provided for all marketed alfalfa varieties by the National Alfalfa & Forage Alliance (https://www.alfalfa.org/varietyLeaflet.php). 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. Alfalfa and all perennial legumes are intolerant of coverage by ice sheeting. Ice sheets can damage alfalfa crowns and cause buildup of carbon dioxide around the plants.

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, 20, and 21), 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.

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., 2015).

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 (Table 22). However, it does cause bloat in ruminants. 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 (Yost et al., 2015). The variety 'Nitro' was specifically developed to supply both forage and nitrogen in crop rotations. It is a non-dormant type that will not consistently overwinter in Minnesota (Sheaffer et al., 1989). For more information on alfalfa management see *Alfalfa and Alfalfa Improvement* (Hanson et al., 1988), and *Alfalfa Management Guide* (Undersander et al., 2015). Many alfalfa varieties are described in Minnesota Varietal Trials Results (annually revised by the Minnesota Agricultural Experiment Station).

CULTURAL PRACTICES FOR FORAGE LEGUMES

ESTABLISHMENT

Establishing small-seeded legumes is more challenging than for large-seeded annual crops such as corn, soybean or small grains. Seedlings are fragile and develop slowly (Figure I). Time and resources spent on 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 (described as variety not stated, VNS). 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:

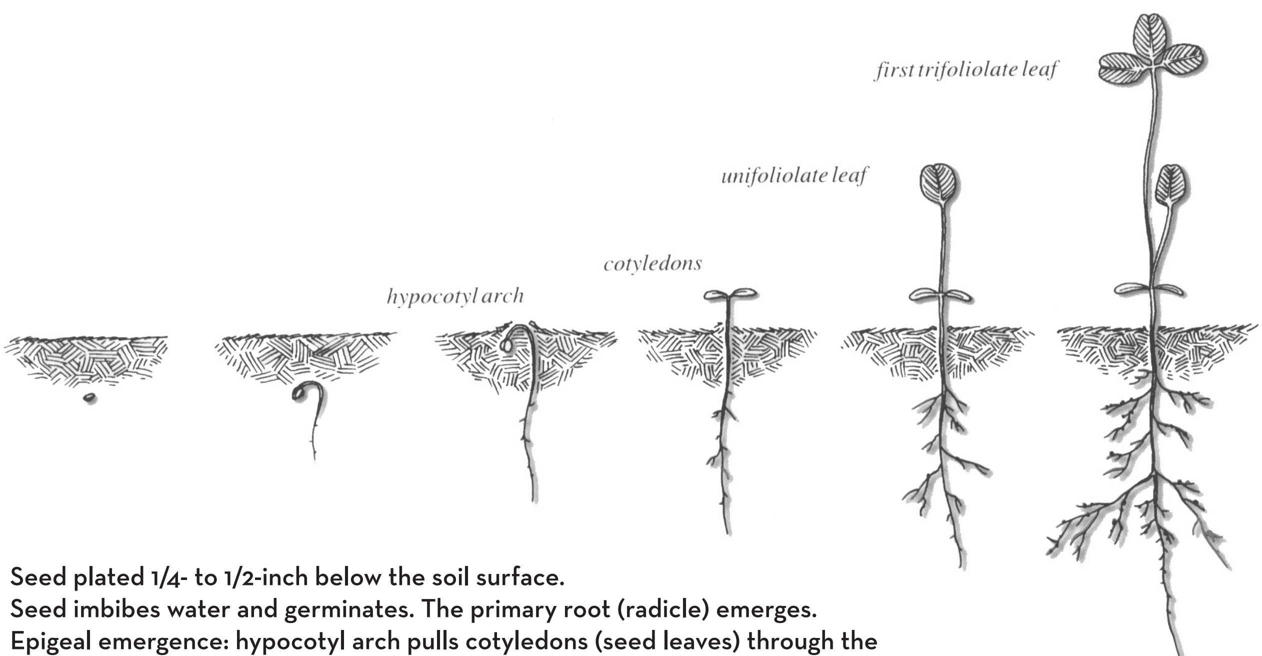
- variety name
- percent germination
- percent inert matter
- percent other crop seed
- percent weed seed
- crop species

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

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



1. Seed plated 1/4- to 1/2-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 %)

SOIL FERTILITY

Alternative forage legumes are usually better adapted to low fertility soils than alfalfa. Although alternative legumes have greater productivity if fertilized and grown at soil pH of 6 to 7, birdsfoot trefoil and many of the clover species tolerate lower soil pH compared to alfalfa and can be more economical to grow because less lime is required. To maximize production, soil testing is recommended, as is fertilization with nutrients and lime as needed (Kaiser et al., 2011). Legume yield and persistence is most often affected by potassium (table 8), phosphorus, and sulfur availability and on some soils boron is required. Nitrogen fertilization is seldom required due to biological nitrogen fixation, but a kura clover yield response has been observed on sandy soils at Becker, MN (Table 30).

Animal manures should be considered as an important source of nutrients for legumes. Manure can be applied before seeding or to established stands either 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. The legume best adapted to field conditions that also meets user needs should be selected. Soil fertility should be tested and fertilizer amendments or manures applied, when appropriate. Existing species and weeds should be evaluated and controlled the fall before seeding.

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 before seeding 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 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. Therefore, broadcasting seed on the soil surface followed by dragging or harrowing is a risky practice because of the uncertain depth of seeding.

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 have been established based on seed size and seedling vigor (Table 31). With rough, loose seedbeds, higher seeding rates may provide some advantages. More seeds develop into seedlings with increased seeding rates, but 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. Mixtures may also reduce weed invasion.

Recommended seeding rates for a variety of legume/ perennial grass mixtures are shown in Table 32. Seeding rates can be refined somewhat if seeding equipment allows precise seed placement and good seed-soil contact.

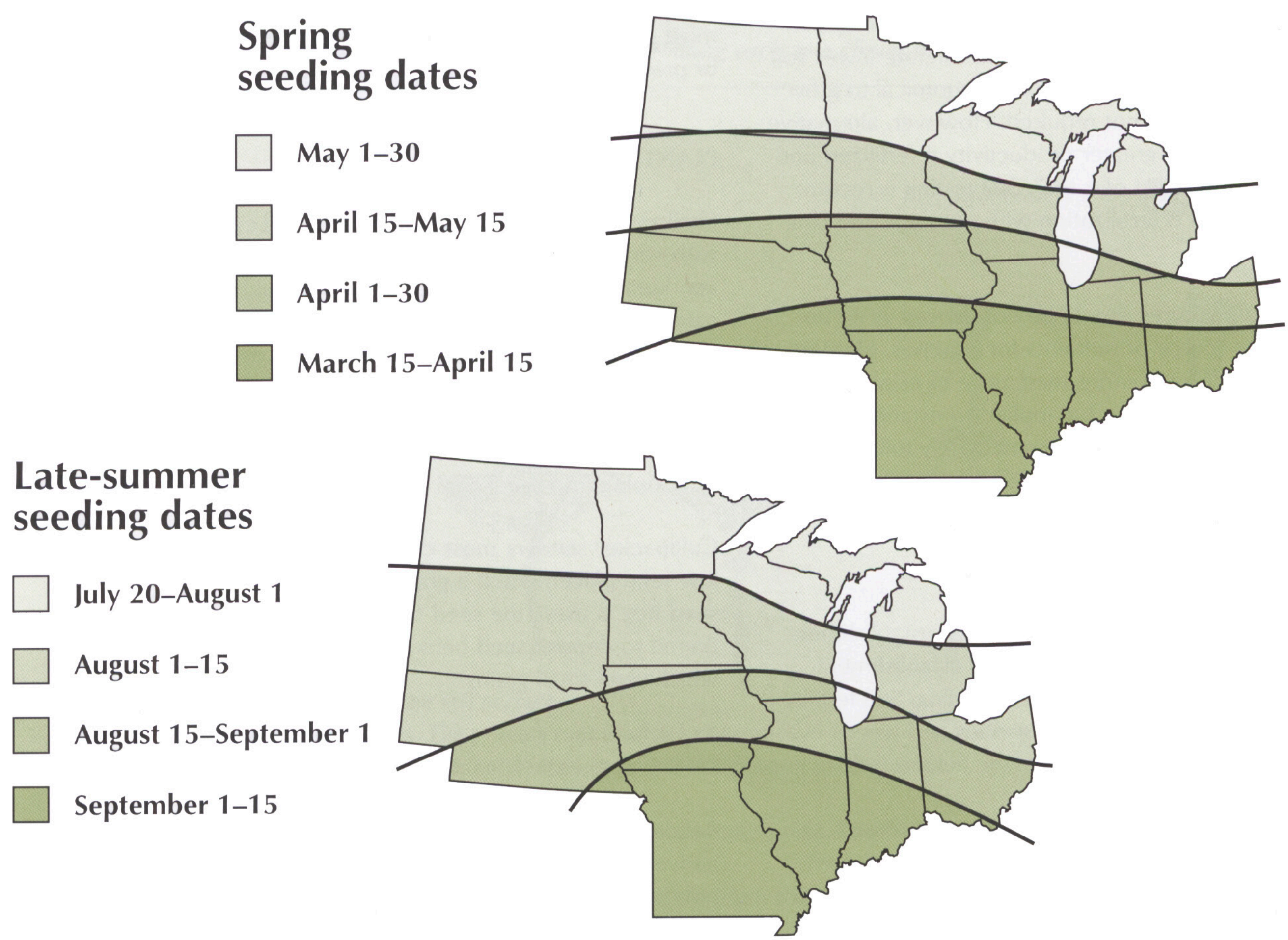
TIME OF ESTABLISHMENT

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., 2015). Legumes with low seedling vigor like birdsfoot trefoil and kura clover should be planted earlier in the range of seeding dates for a region. All legumes should be planted early enough to have undergone contractile growth before a killing frost. Contractile growth is a physiological process that occurs 8-10 weeks following seeding when the cotyledons are pulled below the soil surface to form a crown.

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 seedling growth, and late spring seedings may result in more seedling mortality. Spring is the only option for no-till seeding of perennial legumes into grass sods.

Summer seedings - In regions with 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

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



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 trifoliate leaves to survive the winter. Seeding beyond the recommended seeded dates in the summer may result in injury or slow growth the following spring.

Late fall and winter seedings - Dormant or frost seeding at times outside of the normal growing season provides a low cost alternative approach that minimizes tillage and provides for early spring legume growth ahead of perennial and annual weeds. Dormant seedings, however, are generally less successful than spring and summer seedings into tilled soil (Table 33). 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 (Table 34).

Small grain companion crops are excellent for reducing wind and water erosion of soil, but compete with legume seedlings for nutrients, moisture, and light, and therefore reduce establishment and yield compared to when weeds are controlled with herbicides (Table 13). 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 30 pounds per acre or less. A birdsfoot trefoil companion crop has been used for successful summer seeding of kura clover (Table 13). Birdsfoot trefoil has low seedling vigor but forms ground cover faster than kura clover.

Allowing small grains to mature for grain frequently results in legume stand failure. It is recommended to either graze the small grains when they are still vegetative or to harvest for hay at the boot stage in order to reduce competition from the small grain. 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 can often be controlled by an early clipping or grazing (about 30 days after seeding). Herbicides are an alternative for weed control but may have crop stage or harvest interval restrictions (https://appliedweeds.cfans.umn.edu/herbicides).

MINIMUM TILL SEEDING PASTURE RENOVATION

Legumes are frequently used for renovation of existing pastures (Table 14). 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 broadleaf weeds and brush that can compete with new seedlings. Perennial broadleaf weeds such as 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 label guidelines for herbicide 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 effectiveness of dormant and frost seedings.
- Apply herbicides to suppress grass growth. Several herbicides are available to suppress perennial grasses. Non-selective herbicides such as Roundup are applied before interseeding whereas other herbicides that legumes have tolerance to, such as Pursuit, can be applied post-seeding to suppress grass. Apply herbicide following label guidelines (https://appliedweeds.cfans.umn.edu/herbicides).
- 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.
- For seedbeds that have been tilled and with less than 30 percent surface residue or without intact sod, conventional grain drills and cultipacker 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. The freeze-thaw 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 seedlings. When grass begins shading the legume seedlings, use a heavy stocking rate on small areas (i.e., “mob graze”) and attempt to graze to a 3- to 5-inch stubble height within a few days. Clipping or selective use of herbicides is an alternative approach.

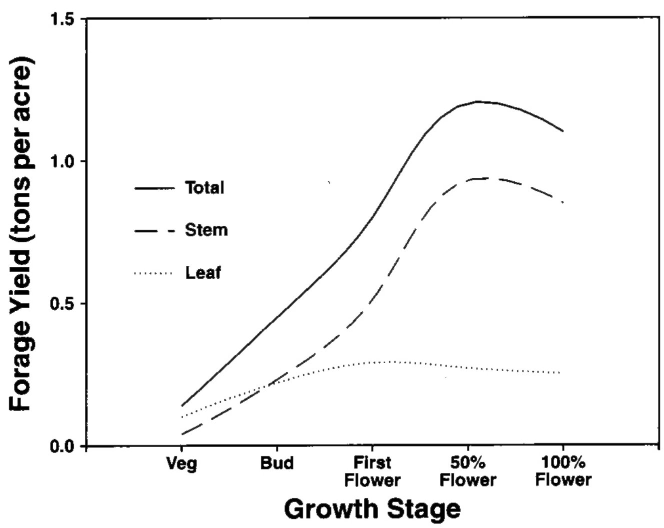
HAY AND SILAGE HARVEST MANAGEMENT

While yield increases with increased maturity, the forage quality of legumes decreases (Figure L). Cutting schedules with more frequent harvests (e.g. a four-cut schedule) usually have greater nutrient concentrations but lower yields compared with less frequent harvests (e.g., two- or three-cut schedules) (Tables 6, 20, and 21).

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

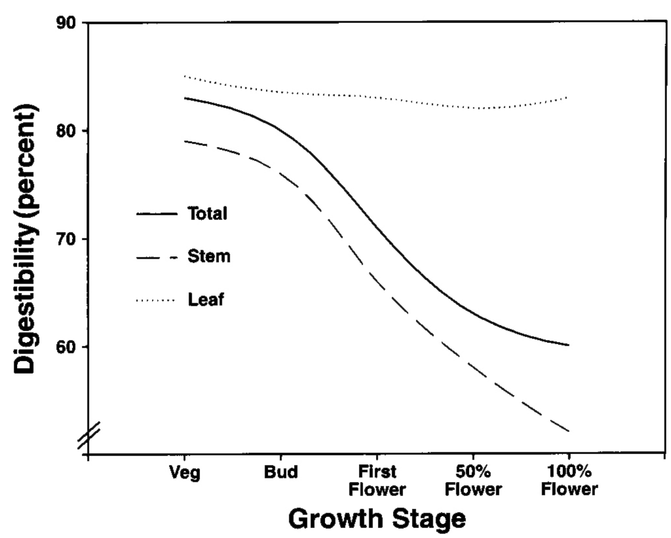
Upright legumes like alfalfa or red clover should have a minimum rest period of 30 days between cuttings for long-term stand persistence. More frequent defoliation results in depletion of carbohydrate reserves and stand depletion. More prostrate legumes like ladino white clover, kura clover and cicer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

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



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



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 initiated when they are in the vegetative stage and 10 to 14 inches in height. Short legumes like white clover and kura clover should be grazed when they are five to eight inches in height.

Following grazing, most grasses and legumes will begin regrowth within one week. Short grazing periods, from one-half to three days, will limit animal grazing of the regrowth and will enhance the persistence of desired forages. Grazing periods greater than one 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 several years of grazing.

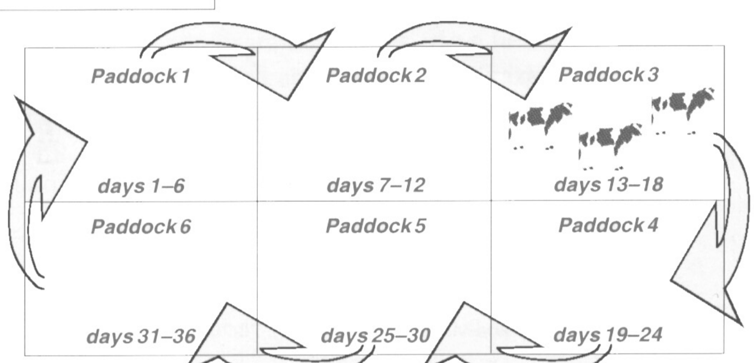
Since legume development can be affected by temperature, drought, and fertility, it is important that you let plant development tell you when to harvest. Legume grazing is usually initiated at vegetative stages.

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).

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

(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.**



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.

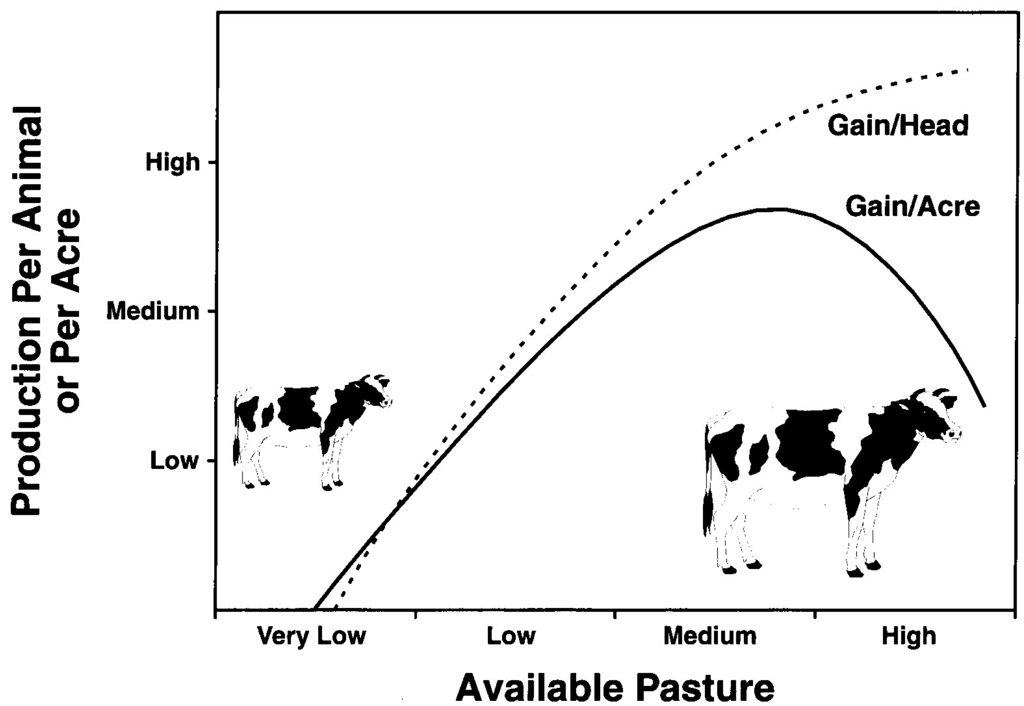
Using a four-week rest interval, most legumes should be grazed to between two and four inches of stubble height. Increasing the stubble height will allow a more rapid regrowth and will enhance the legume's persistence.

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 production per acre and production 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 33

USING LEAST SIGNIFICANT DIFFERENCES

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. Forage yield (tons per acre) of Kura clover varieties at Arlington, Wisconsin.

		Forage Yield (tons per acre)			
Variety	**Species**	**2012[a]**	**2013[b]**	**2014[b]**	**2015[b]**
Endura	Kura	0.41	3.82	3.95	3.45
Cossack	Kura	0.36	3.25	3.60	3.22
Everlast	Kura	0.53	4.35	4.11	3.26
NF-93	Kura	0.37	3.29	3.54	3.02
LP-C3[c]	Kura	0.35	3.78	3.91	3.41
EB-C3[c]	Kura	0.43	3.81	4.11	3.66
C328	Red	0.79	5.01	3.85	3.26
Kopu II	White	0.55	3.55	2.27	1.83
White x Kura	Hybrid	0.44	2.92	1.55	1.89
Ameristand 4071TQ	Alfalfa	0.50	5.18	5.55	4.37
Average		0.47	3.89	3.64	3.14

[a] Trial seeded April 23, 2012 and harvested on August 27, 2012.
[b] Trial harvested 4 times per year at approximately 30 day intervals in 2013 to 2015.
[c] Experimental entries from the University of Minnesota.

Data provided by Kenneth Albrecht, University of Wisconsin.

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.

Site/Variety	Whole Plant	Herbage	Root [a]	Rhizome [b]
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] Root biomass includes roots, crowns, and rhizomes in 0-15 cm of the soil.
[b] Rhizomes were included as a fraction of the root yield.

Source: Genrich et al., 1998. *Crop Sci.* 38:735-741.

Table 6. 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/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. Forage yields (tons per acre) of irrigated and droughted legumes. Forage quality (CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber; and NDFD, neutral detergent fiber digestibility) of irrigated and non-irrigated legumes at July harvest in 2000.

			Forage quality (%)			
Water regime	**Legume**	**4-year yield total**	**CP**	**ADF**	**NDF**	**NDFD**
Irrigated	Kura clover	13.5	18.1	29.5	35.0	46.0
	Alfalfa	20.8	15.4	37.3	46.0	45.1
	Red clover	16.5	18.3	33.7	41.2	42.2
	Birdsfoot trefoil	15.9	14.8	36.0	43.1	40.4
	Cicer milkvetch	15.5	18.2	30.7	36.7	50.1
	Average	16.4				
	LSD[x] (0.05)	2.3	1.3	1.6	2.5	2.6
Drought	Kura clover	5.0	19.8	27.5	32.9	54.2
	Alfalfa	11.8	18.4	34.5	43.4	45.2
	Red clover	7.6	21.1	33.2	41.1	47.2
	Birdsfoot trefoil	8.0	18.8	30.5	38.5	46.5
	Cicer milkvetch	8.6	22.7	29.6	36.6	58.4
	Average	8.2				
	LSD[x]	2.0	1.4	2.5	3.0	4.1
	LSD[y]	4.2	NS	1.9	2.3	3.1

CP = crude protein; ADF = acid detergent fiber; NDF = neutral detergent fiber; and NDFD = neutral detergent fiber digestibility.

[x] LSD = least significant difference at $P < 0.05$ for comparing two legume means *within* water regimes.

[y] LSD = least significant difference at $P < 0.05$ for comparing two legume means *across* water regimes.

Source: Peterson et al., 1992. Agron J. 84:774-779.

Table 8. Effect of K_2O fertilization on annual herbage yields and stands (groundcover) of Kura clover, birdsfoot trefoil, and alfalfa. [a]

K_2O rate (lb/acre)	Legume	Herbage Yield (T/A) 1994	1995	1996	1997	Groundcover (%) 1997
0	Kura clover	1.8	1.7	1.0	1.7	86
	Birdsfoot trefoil	4.1	2.8	0.5	1.1	35
	Alfalfa	3.5	2.9	1.2	1.6	21
	LSD (0.05)	0.6	0.5	0.3	NS	14
75	Kura clover	3.8	3.2	2.3	3.1	100
	Birdsfoot trefoil	4.3	3.3	0.9	1.4	25
	Alfalfa	5.4	4.0	2.5	3.0	43
	LSD (0.05)	0.6	0.5	0.4	0.5	20
150	Kura clover	4.3	3.6	2.3	3.4	100
	Birdsfoot trefoil	4.0	3.3	0.8	1.2	28
	Alfalfa	5.4	4.7	2.8	3.5	50
	LSD (0.05)	0.3	0.3	0.5	0.5	16
225	Kura clover	4.7	4.2	3.2	3.2	100
	Birdsfoot trefoil	4.0	3.4	1.1	1.1	18
	Alfalfa	5.8	4.9	3.7	3.7	50
	LSD (0.05)	0.4	0.3	0.5	0.5	16

[a] Harvests occured on about 1 June, 15 July, and 1 September. Average maturity at harvest: Kura clover was flowering at the first harvest but vegetative thereafter, birdsfoot trefoil was at late bud-early flower at each harvest, and alfalfa was at early flowering.

Source: Sheaffer and Seguin, 2011. Comm. Soil Sci. and Plant Analysis 42:450-456.

Table 9. 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.

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

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

Table 10. 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
Avg. Daily Gain (pounds/day)	2.65	2.26
Gain (pounds/acre/year)	916	712

Source: Mourino et al. 2003. Agron J. 95:652-659.

Table 11. Average total season leafiness, crude protein, digestability, and neutral detergent fiber concentration of birdsfoot trefoil and kura clover forage, and lamb performance grazing these forages at St. Paul, Minnesota. [a]

Trait	Kura clover	Birdsfoot trefoil
Forage quality		
Leafiness (%)	96.5 [b]	80.8
Crude protein (%)	25.2	22.2
Digestability (%)	82.7 [b]	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] Values are averaged for 4 production years.
[b] Statistically significant differences between species.

Source: Sheaffer et al., 1992. Agron. J. 84:176-180.

Table 12. 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 13. The effect of establishment treatments on seasonal forage yields (pounds per acre) in the post-seeding year at Rosemount, Minnesota.

	1997			
Treatments	**Total**	**Kura clover**	**Birdsfoot trefoil**	**Weeds**
Oat companion crop				
Standard stature oat	5255 c[a]	520 bc	—	4736 a
Semi dwarf oat	4149 d	648 bc	—	3501 b
Birdsfoot trefoil companion crop				
With PPI herbicide	7794 a	1815 ab	5316	663 c
Without herbicide	6847 b	251 c	5925	671 c
Solo-seeding				
With PPI herbicide	5031 cd	2155 a	—	2876 b
Without herbicide	5101 c	620 bc	—	4480 a

[a] Numbers within columns followed by different letters differ statistically. $P < 0.05$.

Source: Seguin et al., 1999. J. Prod. Agric. 12:483-487.

Table 14. Forage yield of kura, red, and white clover no-till seeded into a grass sod. Glyphosate (roundup was used for sod suppression).

	Seedling Year	**Year 1**	**Year 2**
	-------------------- lb / acre --------------------		
Kura clover	1800	5100	4500
Red clover	4000	7100	250
White clover	3200	6000	125

Source: Laberge et al., 2005. Agron. J. 97:1352-1360.

Table 15. Effect of planting material and planting date on Kura clover establishment.

Treatment	Establishment	Spread
	---------- % ----------	---------- cm ----------
Material		
Rhizome	17	12
Rhizome-bud	50	17
LSD (0.05)	11	NS
Planting Date		
April 11	55	32
April 29	26	14
May 15	19	5
LSD (0.05)	15	2

Source: Sheaffer et al., 2008. Can. J. Plant Sci. 88:921-924.

Table 16. 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)		Corn Grain Yield (bushels per acre)	
	1999	2000	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 17. Forage yields of red clover varieties and % of stands at Prairie du Sac, Wisconsin.

	Forage Yield (tons per acre)				Stand Rating (%)	
Variety	2013[a]	2014[b]	2015[c]	Total	9/9/14	10/20/15
Cinnamon Plus	2.19	4.78	3.68	10.65	100	68
Freedom! MR	2.79	4.78	3.83	11.41	100	78
Freedom!	2.55	4.74	3.41	10.70	100	75
Marathon	2.13	4.56	3.42	10.12	100	60
Starfire II	2.49	5.28	4.03	11.80	100	78
Mean	2.43	4.83	3.67	10.93	100	72
LSD (0.05)	0.34	0.53	0.55	1.21	8	18

[a] Trial seeded in 2013 and harvested on August 13 and October 22, 2012.
[b] Trial harvested 4 times at approximately 30 day intervals in 2014.
[c] Trial harvested 5 times at approximately 30 day intervals in 2015.

Data was provided by Heathcliffe Riday, USDA-ARS, Dairy Forage Research Center, Madison, Wisconsin.

Table 18. Forage yield of red clover vartieties seeded in 2015 at Rosemount, MN. [a]

		Total		
Variety	Stand 2017	2015	2016	All Years
	%		(T/A)	
PGI 33	64	3.33	4.72	8.05
Freedom MR	41	3.24	4.70	7.95
Cardinal	64	3.12	4.75	7.87
Marathon	56	3.14	4.66	7.80
Cinnamon Plus	48	2.97	4.73	7.71
Starfire	58	3.00	4.68	7.69
Freedom	43	2.96	4.67	7.62
LSD (0.05)	23	NS	0.26	0.57

[a] Trial harvested 4 times at approximately 30 day intervals each year.

Table 19. Effect of cutting schedules on forage yield (tons per acre) and final stands (percent) of perennial legumes at Grand Rapids, Minnesota.

		Forage Yield			Stands	
Schedule [a]	**Legume [b]**	**1987**	**1988**	**2-yr total**	**1987**	**1988**
2-cuts	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-cuts	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 20. Effect of cutting schedules on forage yield (tons per acre) and final stands (percent) of perennial forage legumes at Lamberton, Minnesota.

		Forage Yield				Stands [c]
Cut/year [a]	**Legume [b]**	**1987**	**1988**	**1989 [c]**	**3-yr total**	**1987**
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 vegatative-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] Forest 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 21. 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-cuts	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-cuts	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-cuts	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 22. Lamb performance during grazing of four legumes.

Year	Alfalfa	Birdsfoot trefoil	Red clover	Cicer milkvetch
Average daily gain (pounds)				
1985 [a]	.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] Means within rows followed by different letters are different (P=0.05; Fisher's LSD).

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

Table 23. Seedling 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]

		Suppression [b]	
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] Legumes were seeded on or about May 15 each year into suppressed sod.
[b] Low and high grass suppressions were obtained by applying 0.5 and 1.5 lbs/acre of glyphosate 24 hours before interseeding of legumes.

Source: Sheaffer and Swanson. 1982. *Agron J.* 74:355:358.

Table 24. 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 Wisconsini 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.

Source: Ken Albrecht, University of Wisconsin.

Table 25. Forage yield (tons per acre) of varieties of birdsfoot trefoil, red clover and alfalfa seeded at Beaver Bay, Minnesota. [a]

Legume	Forage Yield 1984	Forage Yield 1985	Forage Yield 2-yr 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 26. Carrying capacity and heifer performance during grazing of three legume species during two seasons.

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

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

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

Table 27. Forage yield of birdsfoot trefoil varieties at Rosemount, MN.

	Forage Yield (tons per acre)			Stand Rating (%)	
Released Variety	**2011 [a]**	**2012 [b]**	**Average**	**6/17/10**	**6/1/17**
AC-Langville	3.65	4.08	3.86	49	45
Bruce	5.44	4.92	5.18	93	88
Empire	5.11	5.47	5.29	80	86
Norcen	5.30	5.30	5.30	91	83
Pardee	4.52	5.39	4.95	91	83
Experimental Variety					
BuUR 09-2 [c]	4.76	4.83	4.79	90	83
BuPR 09-1 [c]	4.61	5.42	5.01	89	93
NB 90-102 [d]	4.96	4.60	4.78	89	93
MSP 2788 [e]	5.63	5.39	5.51	94	94
MSP 3119 [e]	5.51	5.61	5.55	94	94
MSP 3626 [e]	5.12	6.13	5.62	90	89
MSP 3812 [e]	4.97	5.91	5.43	93	93
Average	4.97	5.25	5.11	87	87
LSD (0.05)	0.59	0.79	0.55	8	10

Trial seeded in May 2010 at a seeding rate of 8lbs/acre.

[a] Trial harvested 3 times at approximately 45 day intervals in 2011.
[b] Trials harvested 3 times at approximately 45 day intervals in 2012.
[c] Experimental variety from USDA-ARS Forage and Range Research Laboratory, Logan, Utah.
[d] Experimental variety from Agriculture and Agri-Food Canada, Truro, Nova Scotia.
[e] Experimental variety from the University of Minnesota.

Severe weather injury during 2012-2013 pervented harvesting in 2013.

Table 28. Forage yield (tons/acre of 12 percent moisture forage) of sweetclover varieties or strains harvested in the year following seeding at North Dakota locations.

Variety or strain	Fargo	Edgeley	Dickinson	Streeter
	(tons/acre)			
Yellow-blossom				
Common yellow	2.7	2.1	1.4	2.1
Goldtop	3.2	2.4	1.7	—
Madrid	2.4	2.6	1.5	2.3
Norgold	1.8	—	—	2.1
Yukon	1.8	—	—	1.7
White-blossom				
Common white	2.5	2.7	1.6	—
Evergreen	3.3	2.9	—	—
Polara	—	—	1.9	1.7
Denta	1.8	—	—	—

Source: Meyer, 2005, University of North Dakota.

Table 29. Forage and nitrogen yield of three perennial legumes in the fall of the seeding year following an April planting. Legumes were grown as green manure crops.

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

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

Table 30. Effect of N fertilization on kura clover herbage, root and rhizome yield (pounds per acre) at Becker and St. Paul, MN.

		Plant Part		
	N rate	**Herbage**	**Root**	**Rhizome**
Becker	0	1330	1046	408
	100	2134	1652	841
	150	2312	2640	1064
	LSD (0.05)	600	550	350
St. Paul	0	6370	1646	257
	100	6000	1885	266
	150	5296	1949	310
	LSD (0.05)	NS	NS	NS

Source: Seguin et al., 2001.

Table 31. Seeding rates (pounds per acre) and seed characterisitics of forage legumes.

Legume	Seeding rate for pure stand	Seeding rate for grass mixture	Seeds per lb	Seeds per sq ft
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 seeding vigor of each species and target populations per square foot.
[b] When seeded in pure stands at recommended rate.

Table 32. Hay, silage and pasture mixture seedling rates suggested for Minnesota.

Legume	Seeding rate lb/acre
1. Red clover or alfalfa	12
with	
Orchardgrass	4
or Meadow fescue	6
or Reed canarygrass	6
2. Red clover	7
Alsike clover	3
Ladino clover	0.5
with	
Orchardgrass	4
or Meadow fescue	6
3. Birdsfoot trefoil	8
with	
Timothy	4
Reed canarygrass	6
4. Kura clover	6
Birdsfoot trefoil	2
with	
Orchardgrass	4
or Reed canarygrass	6
5. White clover	4
with	
Kentucky bluegrass	3
or Meadow fescue	5
or Orchardgrass	4

Table 33. Plant populations in the spring following frost seeding of red clover in December, March and April at three locations. Plant populations of about 20 plants/ft² would be considered satisfactory.

	Empire		Rosemount		Lamberton	
Treatment	2007	2008	2007	2008	2007	2008
Seeding Date	plants/ft²					
December	2 b[†]	9 b	3 b	6 c	0 c	4 c
March	5 a	27 a	3 b	16 b	1 b	30 b
April	5 a	25 a	6 a	25 a	9 a	53 a

Means within columns followed by different letters are different (P=0.05)

Table 34. The effect of companion crops on establishment (Yr 1) and year after seeding (Yr 2) alfalfa yields and net economic returns for the two years at Waseca and Rosemount, MN.

	Alfalfa Yield[a]		
Companion Crop	Yr. 1	Yr. 2	Net[b] return average
	(lb/acre)	(tons/acre)	($/acre)
Oat	419	4.0	800
Wheat	1068	3.7	966
Barley	739	3.7	913
Flax	857	4.0	531
Field pea	544	2.9	345
Brassica	2336	3.9	329
Annual ryegrass	2157	3.6	431
Winter wheat	1270	3.7	294
Weedy Control	1992	3.4	241
LSD (0.05)	503	0.9	103

[a] Alfalfa yields when oat, wheat, barley, flax, and peas were harvested for grain and brassica, ryegrass, and winter wheat harvested for forage. Alfalfa was harvested once in the establishment year, and three harvests in year following harvest.
[b] Net return considering costs and value of companion crop and alfalfa production.

Source: Sheaffer et al., 2014. *Agron J.*106:309-314

APPENDIX B: REFERENCES

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