Determining Alfalfa's Stage of Development

Step 1 - Collect a random sample of approximately 40 stems.

Step 2 - Separate the stems according to the criteria below.

Definition of morphological stages of development for individual alfalfa stems.

Stage number	Stage name	Stage definition
0	Early vegetative	Stem length ≤ 6 inches; no buds, flowers, or seed pods
1	Mid-vegetative	Stem length 6 to 12 inches; no buds, flowers, or seed pods
2	Late vegetative	Stem length ≥ 12 inches; no buds, flowers, or seed pods
3	Early flower bud	1 to 2 nodes with flower buds; no flowers or seed pods
4	Late flower bud	≥3 nodes with flower buds; no flowers or seed pods
5	Early flower	One node with one open flower (standard open); no seed pods
6	Late flower	≥2 nodes with open flowers; no seed pods
7	Early seed pod	1 to 3 nodes with green seed pods
8	Late seed pod	≥4 nodes with green seed pods
9	Ripe seed pod	Nodes with mostly brown mature seed pods

(Sources: Kalu and Fick, 1981. Crop Sci. 21:267-270; Fick and Mueller. 1989. Cornell Coop. Extension Inform. Bull. 217)

Step 3 - Determine Maturity

EXAMPLE OF MSC AND MSW CALCULATIONS

Mean Stage by Weight (MSW)
a. dry stems from each stage and weigh
b. calculate MSW:
[sum (stage number x stage dry weight)]/ total dry weight of all stages

Mean Stage by Count (MSC)
a. count stems in each stage
b. calculate MSC:
[sum (stage number x number of stems in stage)]/ total number of stems

Stem				
Stage	Number	Weight	MSC	MSW
0	5	15	0	0
1	6	47	6	47
3	19	83	57	249
4	8	37	32	148
Total	38	182	95	444

MSC = 95/38 = 2.5
MSW = 444/182 = 2.4

Alfalfa development stages have been related to yield, root carbohydrate concentration, and forage quality (Fig. 10). Management and environmental conditions can alter these relationships, but in general, yield increases, quality decreases, and root reserves decrease then increase with advancing alfalfa maturity.

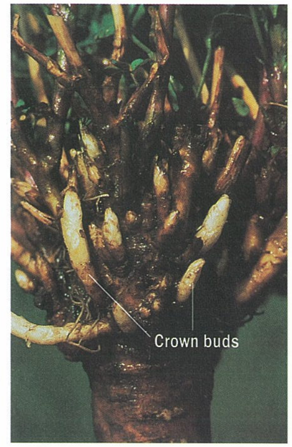


Fig. 11
Alfalfa growth from crown buds.

Vegetative Stage

Alfalfa is in the vegetative growth stage if there are no flower buds, flowers, or seed pods present. When alfalfa begins to grow in the spring or after harvest, there is insufficient leaf area present to produce enough energy through photosynthesis to support growth. During this period, energy for growth comes from carbohydrates and other nutrients stored in the root and crown (Fig. 10). Once vegetative growth has reached about 8 inches, leaf area and photosynthesis have increased enough to supply adequate energy for continued growth and to begin replenishing the root and crown reserves.

Alfalfa growth in the spring is predominantly from crown buds and is dependent on temperature (Fig. 11). Regrowth after harvest comes from both axillary and crown buds and is triggered by a reduction of auxin (hormone) concentration in the buds (Fig. 12). Auxin is produced in the apical meristem of existing stems, and its production decreases as stems mature. The number of stems that develop from either axillary or crown buds is variable but is dependent on variety, developmental stage at the time of harvest, health of the crown, and cutting height. In general, very low cutting height removes axillary buds and forces regrowth to come from crown buds, which delays regrowth.

As alfalfa stems grow taller, the axillary buds begin to develop into stem branches. This branching is more likely to occur in the middle of the stem than from the stem base or tip. In mid-summer when hot temperatures, long days, and low soil moisture levels occur, alfalfa may never reach the late-vegetative stage before flower buds develop.

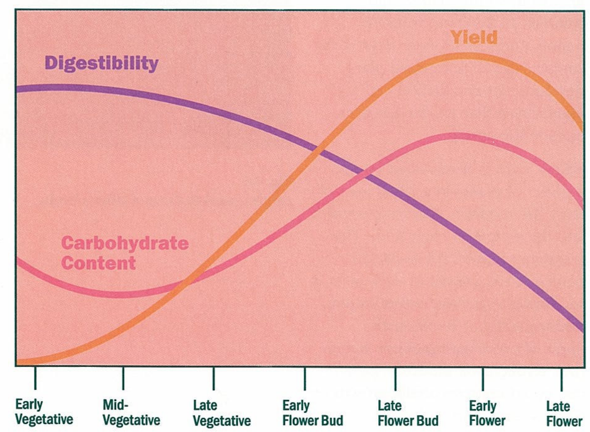


Fig. 10
Relative levels of forage digestibilty, forage yield, and root carbohydrate content during alfalfa growth and development.

Environmental conditions play an important role in determining the rate and amount of vegetative growth. The maximum number of stems on a plant is set within 14 days after harvest and declines as the plant matures. Drought or flooding stress during the first 14 days after harvest can greatly reduce the number of stems a plant will produce in that regrowth period. Drought reduces stem growth more than leaf growth, causing shortened plants that are low yielding but generally high in quality because of increased leaf to stem ratio.

Herbage growth is fastest immediately after harvest when temperatures are 85° to 90° F. However, as alfalfa growth continues, maximum growth rate occurs when temperatures are between 50° and 80° F. Leaf-to-stem ratio declines as the plant matures within each regrowth period. Leaf-to-stem ratio is less for growth in spring than in mid-summer. In addition, warmer temperatures and longer days in the summer cause more rapid plant development and greater cell wall lignification than cooler temperatures in the spring.

Alfalfa yield is determined by the number of plants in a given area of land, the number of stems per plant, and the weight of each stem. The maximum number of stems per plant and the weight of each stem is set during vegetative development. Consequently, it is extremely important that management factors (pH, fertility, soil moisture, pests) that could improve alfalfa growth or development during this period be optimized.

Environmental conditions (temperature and water availability) interact

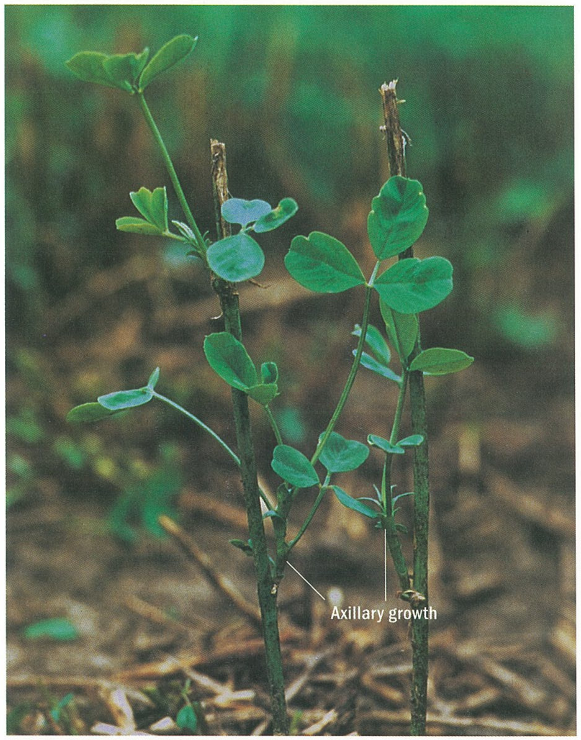


Fig. 12
Alfalfa growth from axillary buds.

nitrogen fixation process. Waterlogged soils inhibit oxygen and nitrogen movement through the soil to the roots and nodules. Harvesting alfalfa herbage will also cause nitrogen fixation to decline until herbage regrowth is adequate to supply the nodules with sugars (energy) from photosynthesis.

Evaluate when it is best to take a seeding harvest. New plantings should not be harvested until sufficient carbohydrates have been stored in the roots to support rapid regrowth. Depending on growing conditions, this generally occurs around 60 days after emergence, when the alfalfa has begun to flower. Delaying harvesting beyond 60 days generally does not improve regrowth and may dramatically reduce forage quality.

Identifying Stages of Alfalfa Development

There are inherent difficulties in identifying stages of alfalfa development. During the initial spring growth, or after harvest, crown and axillary buds may break dormancy and begin to grow at different times. This results in stems on a single alfalfa plant that vary in maturity. For example, on a single plant there can be stems that have begun to flower and other stems that won't flower for several weeks. To overcome this variability in maturity, a system was developed that determines alfalfa's stages of development based on the weighted average stem development.

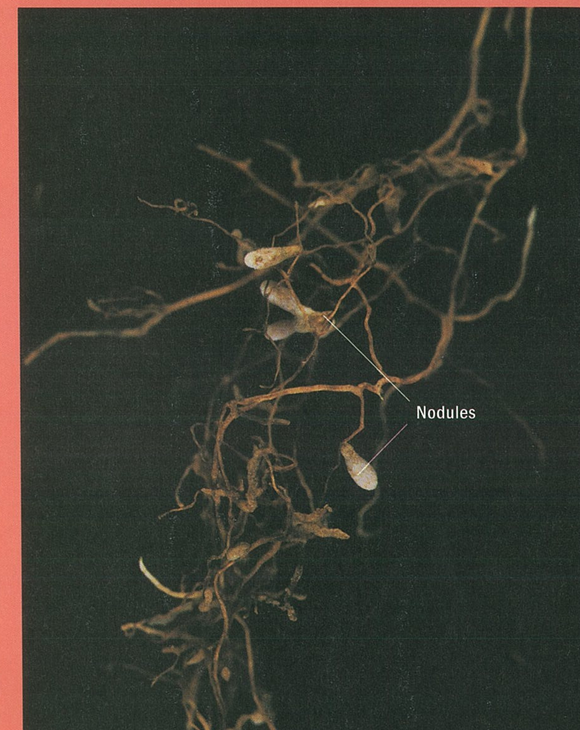


Fig. 9
Nodules on secondary alfalfa roots.

Provide adequate levels of available nutrients. Adequate levels of nutrients are important for alfalfa shoot and root development. Nutrient levels are especially important during early seedling establishment to insure a root system large enough to support maximum herbage growth for the life of the plant.

Minimize risks of seedling diseases. Soil moisture is necessary for nutrient absorption by the roots and rapid seedling development, but excessive soil moisture can stop root growth. Wet soil conditions also can lead to fungal diseases, such as *Pythium* (damping off), *Phytophthora* (root rot), *Aphanomyces* (damping off), and *Rhizoctonia* (stem and root canker), all of which can cause serious establishment problems. Seed- and soil-applied fungicides can reduce the infection rate of these diseases. However, planting alfalfa in soils that are well drained can equally reduce the incidence of these "wet-soil" diseases.

Sclerotinia (stem rot) fungus survives in the soil as sclerotia (hard, pea-sized masses of fungus) and produces infection spores when temperatures are cool and soils are moist. This occurs during the fall in the Midwest. *Sclerotinia* infects alfalfa only during establishment. For this reason, summer-seeded alfalfa in the Midwest is highly susceptible to infection by *Sclerotinia* if the sclerotia are present in the soil. In areas where *Sclerotinia* has been a problem, plowing to bury the sclerotia before summer seeding alfalfa, or seeding alfalfa in the spring can dramatically reduce the incidence of this serious disease.

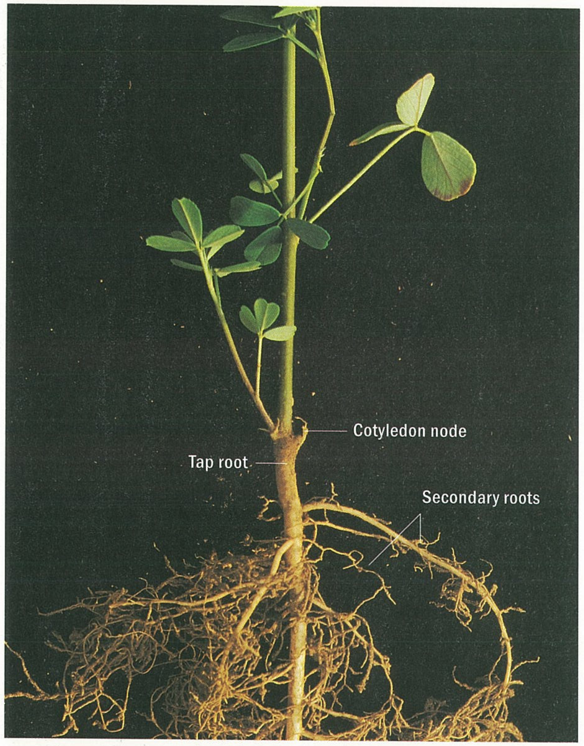


Fig. 8
Primary tap root of a young alfalfa plant.

Insure adequate amounts of *Rhizobium* in the soil. *Rhizobium* bacteria may not be present if there is no recent history of alfalfa being grown in the soil or if the soil pH is low. Once pH is corrected, using preinoculated alfalfa seed or inoculating the seed with live *Rhizobium* prior to planting will provide adequate bacteria. In general, inoculation is an inexpensive way of insuring that adequate *Rhizobium* are present in the soil.

Optimize nitrogen fixing potential. Conditions that are ideal for alfalfa plant growth are also ideal for maximum nitrogen fixation. Low soil pH (below 6.5) limits nodulation and the availability of molybdenum, which is essential in the

TABLE 1
PROBABLE OCCURRENCE AND/OR SEVERITY OF ALFALFA DISEASES BY AGE OF STAND AND HARVEST.

	YEAR					HARVEST			
Disease	**Seeding**	**1st**	**2nd**	**3rd**	**4th**	**1st**	**2nd**	**3rd**	**4th**
Spring Black Stem	H	H	H	H	H	H	M	O	L
Summer Black Stem	H	H	H	H	H	O	M	H	M
Common Leaf Spot	H	H	H	H	H	M	H	H	H
Phytophthora Root Rot	H	M	M	M	M	M	H	H	H
Aphanomyces Root Rot	H	M	M	M	M	H	H	H	H
Downy Mildew	H	M	M	M	M	H	L	L	H
Pythium Seedling Rot	H	O	O	O	O	H	L	L	L
Anthracnose	M	H	H	H	H	O	L	H	H
Verticillium Wilt	O	L	M	H	H	H	L	M	H
Fusarium Wilt	O	L	M	H	H	L	L	H	H
Bacterial Wilt	O	L	M	H	H	L	M	H	H
Fusarium Crown Rot	O	L	M	M	H	H	M	M	H

Probability of occurrence and/or severity.
O = none, L = low, M = moderate, H = high

(source: Dr. Craig R. Grau, University of Wisconsin) to reduce alfalfa yield over a "normal" growing season. When three harvests are taken in a growing season, the relative yield ratios are 7:5:3. That is, if the first harvest yields 3 tons/acre, then the second and third harvest will yield approximately 2.1 and 1.3 tons/acre, respectively. The relative yield ratio is generally 9:7:5:3 in a four-cut system.

Shortening days and declining temperatures in the fall can cause some alfalfa varieties to change their vegetative growth pattern. The amount of stem growth in the fall serves as the basis for assigning varieties a relative fall dormancy rating. A fall dormancy of 1 indicates the greatest fall dormancy and least amount of fall growth, while a rating of 9 indicates the least fall dormancy and greatest amount of fall growth. Usually, the more fall dormant the variety, the slower it regrows after harvest but the better it survives adverse winter conditions.

During the fall, dormant varieties alter the chemical processes that prepare the plant for winter survival. Some of the starch in the crown and root is converted into sugars that function as antifreeze and help keep the crown, crown buds, and root from freezing at temperatures well below 32° F. Crown buds, which will be the source of growth the following spring, are formed during the fall.

Dormant alfalfa varieties that have had proper climatic conditions to prepare for winter survival can survive temperatures of about 5° F. Plant tissue below the soil surface is insulated from cold air temperatures by soil and layers of snow. When there is no snow cover, extremely cold air temperatures can cause the soil temperature to drop below 5° F. This will injure or possibly kill the alfalfa plant.

Management Tips

Provide adequate levels of available nutrients. Adequate levels of soil nutrients are essential to maximize alfalfa growth. They are especially important during vegetative development because relatively large amounts of nutrients are needed to support alfalfa's rapid growth during this stage. Some nutrient deficiencies are not readily visible in alfalfa, but they can decrease yield.

Control insect populations. Insect feeding can be extremely damaging to alfalfa, especially during vegetative development. Insect feeding causes stress to the plant and reduces its ability to achieve maximum yield. Wounds from insect feeding not only weaken the plant but also predispose it to diseases and premature stand thinning.

Minimize disease infestations. Diseases infect and become evident at different periods within a growing season and within a plant's life (Table 1). Unfortunately, most alfalfa diseases are neither effectively nor economically controlled with chemicals. Management practices such as maintaining optimum soil fertility, selecting a well-drained site, selecting disease resistant alfalfa varieties, mowing younger stands before older stands, and cleaning equipment between fields are the best ways to reduce the incidence of alfalfa diseases.

Flower-Bud Stage

The flower-bud stage occurs between the appearance of the first flower bud and a flower opening. The flower bud is the initial reproductive structure of alfalfa. It is formed in the axil of unopened leaves in the apical meristem. Alfalfa flower buds are initially distinguished as solid bulbous masses at the stem tip (Fig. 13). They are attached to a peduncle (flower stem) by a branch stem called a pedicel. Each floral structure (peduncle, pedicel, and bud or flower) of alfalfa is known as a raceme and may have from 8 to 14 flower buds (Fig. 14).

The formation and first appearance of a flower bud marks a major transition in alfalfa growth and development. Up to this point, the alfalfa plant has been utilizing its energies from photosynthesis to build a larger photosynthetic factory (more leaves) and to store some energy in the crown and roots. When floral development begins, the plant starts to shift a large portion of its energy into flower and ultimately seed production.

Alfalfa has an indeterminate growth pattern, which means it continues to produce both vegetative (leaves and stem) and reproductive (bud) structures simultaneously. Because of this growth habit, it is possible to have a single alfalfa stem with newly-emerged leaves, flower buds, flowers, and seed pods. Continued vegetative growth results in alfalfa yield increasing through the flower-bud and early flower stage of development (Fig. 10).

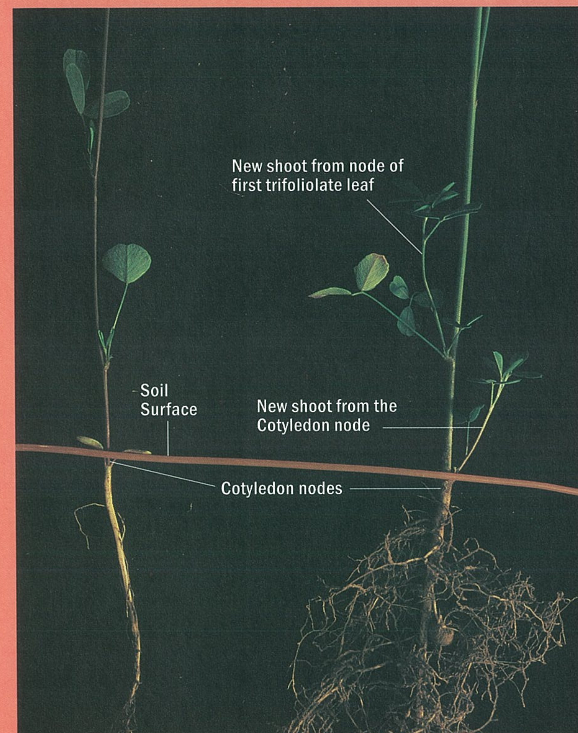


Fig. 7
Contractile growth of alfalfa pulling the cotyledon nodes below the soil surface.

the nodes pulled farther below the soil surface, than less dormant varieties. Plants with deep crowns tend to be more persistent than plants with shallow crowns because they have increased soil protection from extremely cold air temperatures. Because of their location, the axillary buds that are pulled below the soil surface during contractile growth are referred to as crown buds.

The radicle begins to thicken and develop into the primary tap root (Fig. 8). At the same time, smaller secondary roots begin to develop on the radicle as it grows deeper. The location and extent of secondary root formation is genetically regulated. Root growth during establishment is generally about 80% of herbage growth. That is, for every ounce of herbage growth, there is 0.8 ounce of root growth. However, under hot temperatures (> 90° F), root growth may drop to 40% of herbage growth.

Within four weeks after germination, root hairs on the radicle become infected with the nitrogen fixing bacteria, *Rhizobium meliloti*, and begin to form nodules, (Fig. 9) where atmospheric nitrogen fixation occurs. The initiation and rate of *Rhizobium* infection is variable depending on the soil nitrogen content and the rate of seedling growth and development. This infection of alfalfa root hairs is specific to the *Rhizobium meliloti* bacteria. *Rhizobium* bacteria that infect other legumes (e.g. soybeans) are incapable of infecting alfalfa, and *Rhizobium meliloti* is incapable of infecting other legumes. Only about 5% of the alfalfa root hairs become infected, and only about 30% of these infections result in nodule formation, regardless of the quantity of *Rhizobium* present.

Management Tips

Avoid planting later than recommended dates. Air temperatures of 26° F or lower for only a few hours can kill an alfalfa seedling when the second trifoliolate leaf has just emerged. However, following contractile growth, alfalfa stems may be frosted but the plant can survive freezing air temperatures because the crown buds are protected below the soil surface. Summer-seeded alfalfa generally needs a minimum of six weeks of growth after emergence to survive winter without injury and maximize yields the following year.

Establishment

The establishment phase in alfalfa growth and development is generally considered to occur between seedling emergence and harvest of seedling growth. While it is readily acknowledged that alfalfa establishment may continue well beyond the first harvest, the major steps in establishment are complete or nearly so by the time of the first harvest.

Cotyledons may turn green after opening, but they have limited photosynthetic activity. The epicotyl produces the first leaf, which is unifoliolate (single leaflet/leaf). The meristematic region of the epicotyl continues to grow, adding trifoliolate (3 leaflets/leaf) or multifoliolate (>3 leaflets/leaf) leaves on alternate sides of the developing stem (Fig. 6). The cotyledons begin to shrivel as their nutrients are used to support seedling growth.

While the epicotyl continues to add stem, leaves, and flowers, the bud in the axil of the unifoliolate leaf begins to grow and form a secondary stem. Additional secondary stems develop from the axillary buds at the cotyledon nodes (the point where cotyledons attach to the stem). Temperatures of 68° to 85° F during early seedling development are optimum for growth and development; however, as the seedling continues to develop, slightly cooler temperatures (60° to 75° F) are ideal. Alfalfa growth and development during establishment is slower (24 to 33 days longer to reach early flower) than that of regrowth.

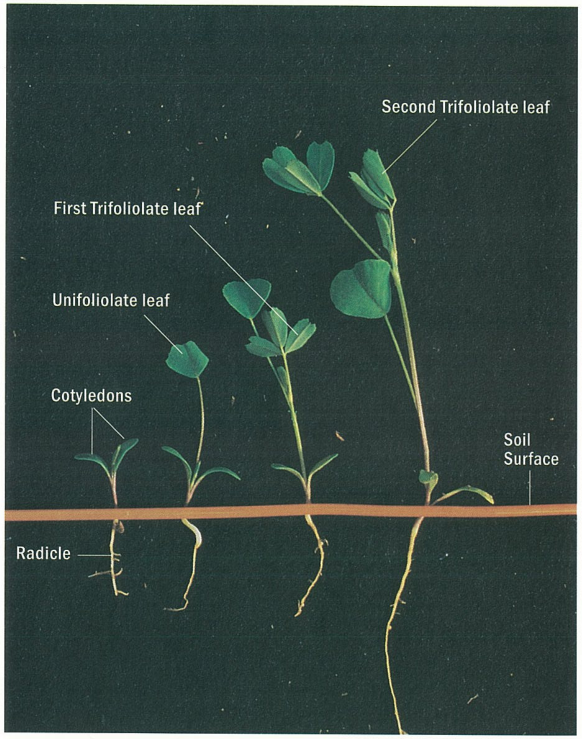


Fig. 6
Alfalfa seeding development.

The radicle tip continues to grow deeper into the soil. The hypocotyl and upper portion of the radicle begin contractile growth, a process where these organs enlarge laterally and contract vertically. Contractile growth pulls the cotyledonary and unifoliolate nodes below the soil surface. (Fig. 7)

Contractile growth begins as early as one week after emergence and is usually complete within 16 weeks. The result of contractile growth is the pulling of axillary buds below the soil and the formation of the crown (area between the soil surface and the cotyledonary nodes). Alfalfa varieties with greater fall dormancy tend to have more pronounced contractile growth, with

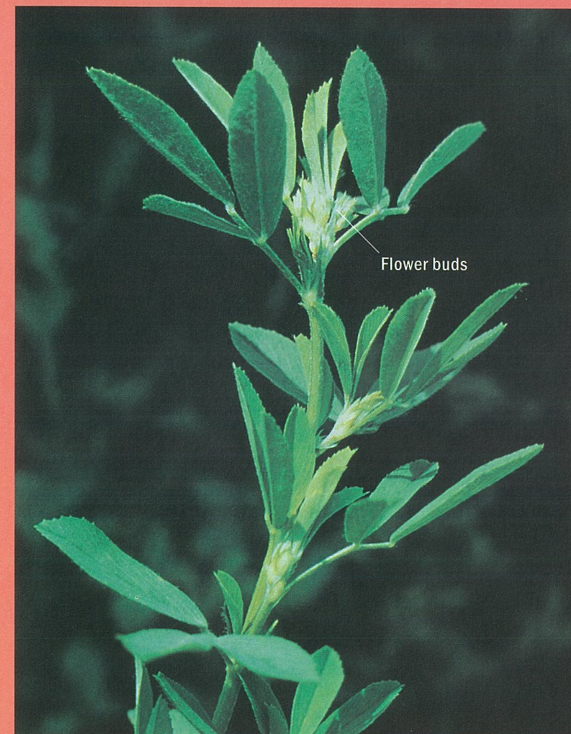


Fig. 13
Flower buds at the apex of an alfalfa shoot.

The onset of floral development is controlled primarily by temperature and photoperiod. Flower buds may appear three weeks earlier on alfalfa regrowth in mid-summer than in the spring when temperatures are lower and the photoperiod shorter. Flower buds begin to appear at the 6th through 14th node on the stem, depending on environmental and genetic factors. Flower bud formation usually begins at lower nodes (6th through 8th) in the summer than in spring or fall. After the first flower bud appears, a new bud will appear about every three days until the stem is harvested or reaches maturity.

The appearance of the first flower bud usually indicates that forage quality is beginning to rapidly decline (Fig. 10). This is, in part, due to the loss of lower leaves because of shading by leaves higher on the stem, along with the continued thickening and lignification of cells in the stem. Some producers begin harvesting when buds first appear because of rapid decline in quality. However, root carbohydrate reserves used to support early vegetative growth have not been fully replenished at the bud stage (Fig. 10).

Management Tips

Watch for pests. Some insect pests feed on the alfalfa bud and flower. Excessive numbers of these insects in an alfalfa field can remove buds as they form, causing the casual observer to assume that the alfalfa has not begun to form buds. If initiation of alfalfa harvesting is based on plant development, then careful monitoring of insect populations and plant development are necessary to avoid this situation.

Understand the risks of harvesting during the bud stage. Alfalfa varieties developed in the past 10 years have greater disease resistance than older varieties. With adequate fertility and pest control, these newer varieties can survive aggressive harvest schedules better than older varieties. In addition, newer alfalfa varieties have been selected for rapid regrowth, which increases their yield potential (Fig 15). Faster regrowth is a result of decreased auxin production in the apical meristem during the flower-bud stage, allowing earlier regrowth from crown and axillary buds.

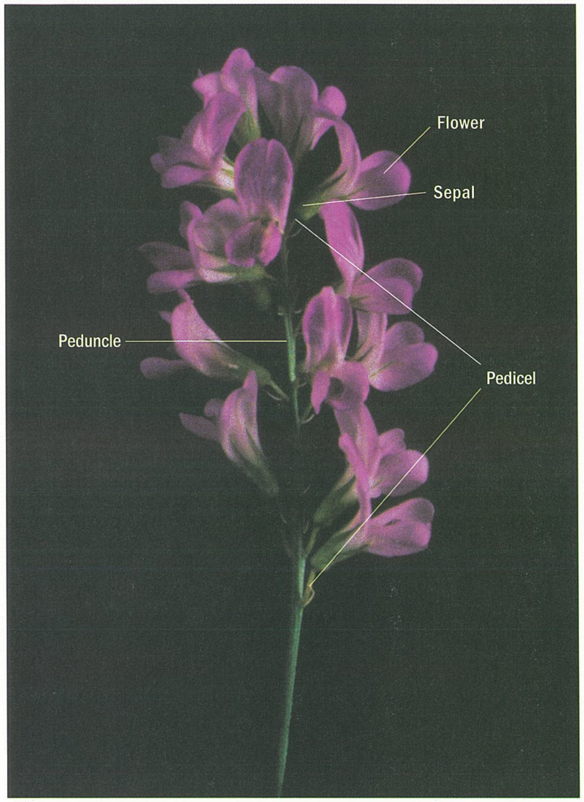


Fig. 14
Alfalfa floral raceme.

Harvesting during the flower-bud stage provides relatively high forage quality, but continuously harvesting at this stage will result in low root carbohydrate reserves and stand decline (Fig. 10). Alfalfa stands that are intended to remain in production for more than three years must periodically be allowed to mature beyond the flower-bud stage in order to replenish root reserves.

Flower Stage

The flower stage occurs from the time that the first flower opens until a seed pod is formed. If environmental conditions are favorable, flower buds will develop into flowers. The time between when flower buds form and when buds open to expose the petals is generally about five days, but is highly dependent on the environment. In the fall, when there are fewer than 12 hours of daylight, flower buds may wither and fall off without developing into flowers.

The alfalfa flower possesses both female (pistil) and male (stamen) structures. The flower petals (corolla) of alfalfa grown in the United States are usually some shade of purple because of its *Medicago sativa* parentage (Fig. 16). However, alfalfa flower colors can vary from yellow to shades of blue-green depending on parentage.

Alfalfa is typically cross pollinated (pollen from another flower fertilizes the ovules) because of self-incompatibility and self-sterility. Alfalfa pollination is associated with "tripping." Tripping is the release of the stamen and

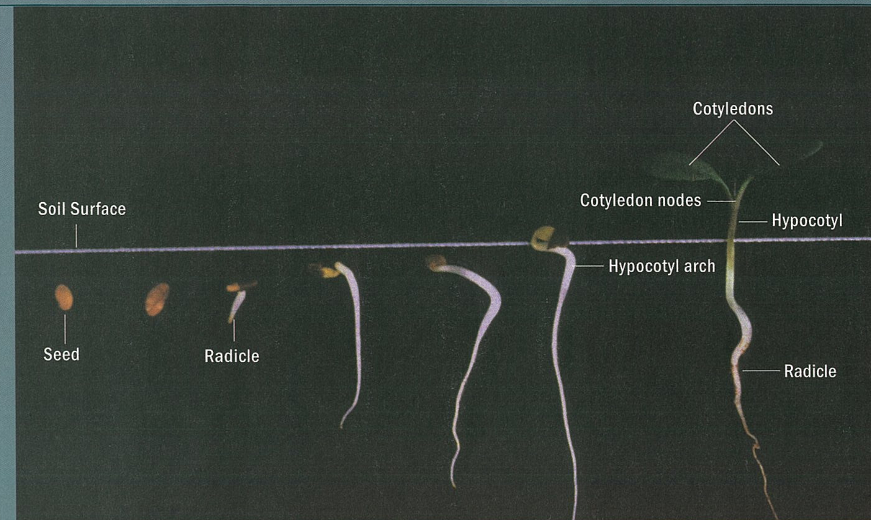


Fig. 5
Alfalfa germination and emergence.

Minimize risk of soil crusting. Soils that crust easily create an additional problem during alfalfa emergence. The germinated seed will die if the elongating hypocotyl cannot penetrate this crusted soil and pull the cotyledons above the soil surface. Excessive tillage can increase the potential for crusting. Irrigation or light tillage may be required to soften or break the crusted layer.

Don't plant alfalfa into established alfalfa fields. Established alfalfa plants release a compound into the soil that reduces germination and growth of new alfalfa seedlings. This effect is known as autotoxicity, or "self toxic." The extent of autotoxicity depends on several variables, including the amount of alfalfa residue in the soil when the new alfalfa seeding is made. To avoid alfalfa autotoxicity, grow a crop other than alfalfa after plowing under or chemically killing an established alfalfa field. This practice also helps reduce disease and insect populations that may have developed in the alfalfa field.

Management Tips

Store seed at cool temperatures and in low humidity. Many precautions are taken by the certified alfalfa seed industry to ensure that the purchaser receives very high-quality, weed-free seed. Decline in seed quality on the farm can be slowed by storing seed in a cool, dry place.

Reinoculate with Rhizobium bacteria if stored beyond expiration date. Many varieties of alfalfa are inoculated with *Rhizobium* (a bacteria essential for nitrogen fixation) during seed processing. *Rhizobium* live for a limited period depending on environmental conditions. Preinoculated seed stored beyond the *Rhizobium* expiration date (printed on the seed-bag label) should be inoculated again with fresh *Rhizobium* before planting.

Germination and Emergence

Alfalfa seeds begin to germinate after absorbing about 125% of their weight in water. Alfalfa can germinate at temperatures greater than 36° F. However, the optimum temperature for germination is between 65° and 77° F. The rate of germination increases as soils warm because water movement into the seed, along with the rate of other metabolic activities associated with germination, also increases.

Germination begins with the radicle emerging through the seed coat near the hilum (Fig. 4) and anchoring itself in the soil as an unbranched tap root (Fig. 5). As the radicle tip grows deeper into the soil, the hypocotyl elongates and pulls the cotyledons and epicotyl above the soil surface. This is known as epigeal (in Latin epi = above and geal = earth; or above the earth) emergence. As the cotyledons are pulled above the soil surface, the seed coat falls off, and the cotyledons open to expose the epicotyl.

Management Tips

Optimize seed-to-soil contact. Water, required for germination, moves from the moist soil into the seed. Poor seed-to-soil contact causes poor or sporadic germination. In conventionally tilled seedbeds, optimum seed-to-soil contact is achieved when the seedbed contains no soil clods. The use of press wheels or a cultipacker after planting are also beneficial in improving seed-to-soil contact. Many no-till alfalfa plantings fail because they are done when the soil is too wet and the seed furrow does not close, resulting in poor seed-to-soil contact.

Plant no deeper than 1/2 inch. Seeding alfalfa at depths greater than 1/2 inch make it difficult or impossible for the hypocotyl to pull the cotyledons above ground, especially in heavy-textured soils. Alfalfa seedlings that do emerge from deeper than 1/2 inch usually are weaker because of greater energy expenditure during emergence. A firm seedbed is extremely helpful in regulating and maintaining seeding depth.

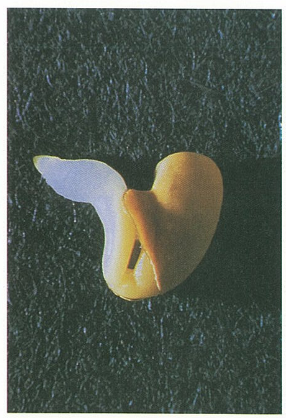
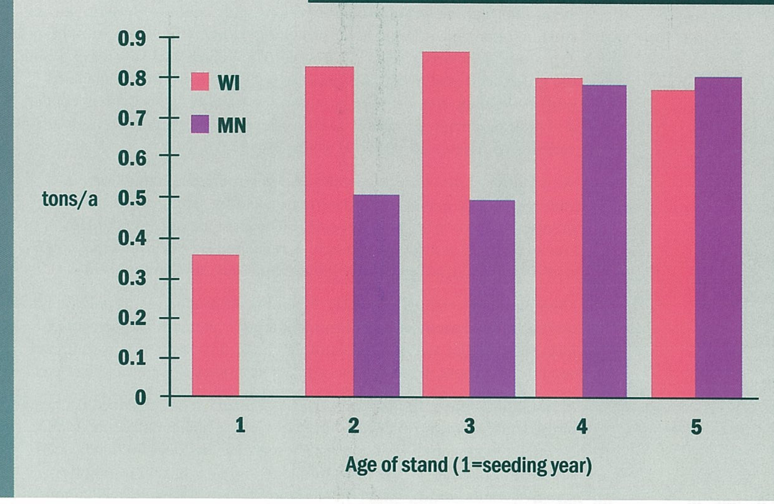


Fig.4
Alfalfa radicle emerging through the seed coat.

Figure 15
YIELD INCREASE OVER "VERNAL" OF TOP VARIETIES IN WISCONSIN AND MINNESOTA



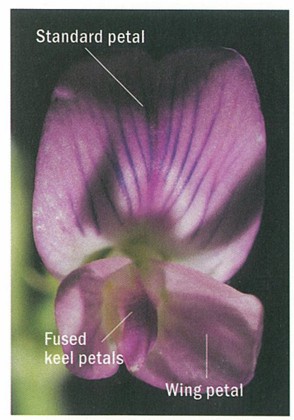


Fig. 16
Alfalfa flower.

pistil from the keel petals. The process is irreversible and ruptures a protective layer of cells covering the pistil. Tripping is a prerequisite for effective pollination and is usually caused by nectar or pollen collecting insects such as honey, alkali, and leaf-cutter bees. After tripping and pollination, pollen usually fertilizes the ovule within 24 to 32 hours. Each alfalfa flower has between 6 and 18 ovules in its ovary, each of which could potentially become a seed. However, only 10 to 12 ovules usually develop.

Management Tip

Know compromises associated with harvesting during flower stage. As alfalfa flowers develop, forage yield reaches it highest point and the energy reserves in the root continue to accumulate (Fig. 10). Producers who want to keep an alfalfa stand for more than three years have used the appearance of the first flower as a signal to begin harvest because it coincides with high carbohydrate levels in the root. Harvesting delays during this stage will cause large reductions in quality and a decline in total yield over the season because fewer harvests are possible.

Seed-Pod Stage

Alfalfa is in the seed-pod stage when the first seed pod appears on the stem. After the ovules have been fertilized, they begin to develop into a seed. As seeds grow larger, they stretch the ovary, which becomes the pod surrounding the seeds (Fig. 17). The corolla withers and falls off exposing the green seed pod, which becomes brown with maturity. Alfalfa seed pods have many shapes, depending on the number of seeds they contain and their parentage. However, seed pods are spiral shaped on most alfalfa varieties common in the United States (Fig. 17).

Seed yield is a function of genetics and environmental conditions. A variety's genetic makeup can determine yield by setting the maximum number of seeds/pod, pods/raceme, racemes/stem, and stems/plant. However, each of these factors also is regulated by environmental conditions, such as temperature, day length, humidity, and soil moisture.

Minimum temperatures above 68° F favor seed production. In addition, low temperatures during seed development tend to increase the percent of hard seed. Long days and low humidity favor flowering, pollination, and seed development. Excessive or deficit soil moisture decreases seed yield.

About 90% of the ± 100 million pounds of alfalfa seed produced each year in the United States is produced in five western states: California, Idaho, Nevada, Oregon, and Washington. These states are ideal for alfalfa seed production because of their low humidity and lack of rain during the summer while seed is maturing and being harvested. Even small amounts of rain during seed maturation and harvest can greatly reduce seed yield and quality.

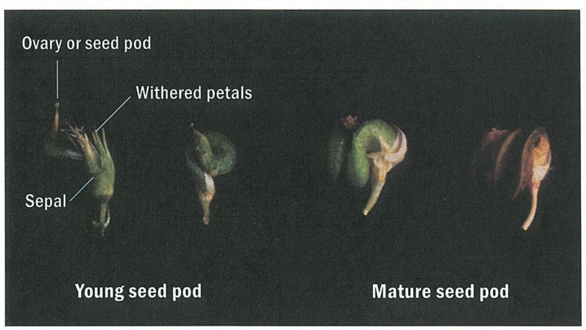


Fig.17
Alfalfa seed pod development and growth.

The Seed

Alfalfa seeds are generally kidney shaped and are yellow-brown to olive green in color (Fig. 2). They are small (2/32" long and 1/32" wide and thick) having about 225,000 seeds/lb and 60 lb/bu. The seed consists of two cotyledons, a radicle (an embryonic root), a hypocotyl (the area of radicle just below the cotyledons), and an epicotyl (an embryonic stem). All of these embryonic plant parts are surrounded by a protective seed coat (Fig. 3). Carbohydrates, proteins, and fats stored in the cotyledons supply the energy needed during alfalfa establishment until the true leaves begin photosynthesis. The radicle becomes the primary root and is the initial anchoring and absorption structure during alfalfa emergence. The epicotyl is the growing point (where the meristematic tissue is located) of the future stem and is protected between the two cotyledons until the cotyledons are above ground and separate. The scar tissue on the seed coat, known as the hilum, is the previous point of attachment of the seed to the pod.

Sometimes the alfalfa seed coat may not be permeable to water, causing what is known as "hard seed." Hard seed can lie dormant in the soil for several weeks or years before germinating. The seed industry takes corrective measures to insure that marketed seed contains a minimum amount of hard seed.

Several compounds (e.g. fungicide, *Rhizobium* bacteria, nutrients, or lime) can be applied to the seed during processing and preparation for marketing. In general, these seed coatings have no effect on seed quality but are placed on the seed to aid in alfalfa growth and development after planting.

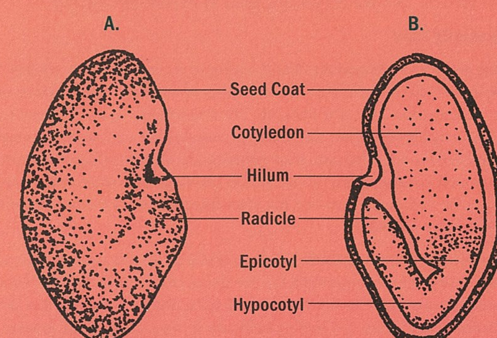


Fig. 3
Diagramatic view of alfalfa seeds
A. External B. Internal.

Stages of Development

Living cells extract energy from glucose through a process called respiration. In the most basic sense, for alfalfa to have sustained growth, glucose production by photosynthesis must be greater than glucose use by respiration.

Alfalfa cells divide at the tip of the stem and root in tissue known as the apical meristem. In the stem, cells below the apical meristem enlarge and develop thicker cell walls which contains more lignin and become less digestible. Leaf cells, on the other hand, enlarge but otherwise change relatively little. Consequently, the oldest and less digestible part of the alfalfa stem is at the bottom, while the youngest and most digestible part is at the top.

In the axil (the point of attachment to the stem) of leaf petioles and stem branches are axillary buds (Fig. 1). Axillary buds contain meristematic (growing) tissue, which can develop into leaves, stem branches, or new stems. The meristematic tissue in the axillary buds was left there by the apical meristem as the axil was formed during stem development. Axillary buds generally remain inactive until the apical meristem begins producing flower buds or is physically removed.

Alfalfa growth and development are controlled by the alfalfa variety's genetic potential interacting with the environment in which it is growing. While the maximum yield potential of an alfalfa variety is genetically determined, its growth changes along with changes in the environment. Environmental conditions must be ideal to achieve maximum yield. Unfortunately, ideal conditions rarely exist in nature. To achieve maximum yield, a producer must manage the environment surrounding the alfalfa plant to provide as near to ideal conditions as possible. Such management practices include selecting the best-adapted variety for the site, maintaining optimal levels of soil fertility and pH, using timely pest control, and following proper harvest schedules. The correct combination of these practices varies from farm to farm and from field to field. This is why a producer needs to understand alfalfa growth and development in order to implement management practices that maximize alfalfa yield, quality, and persistence.

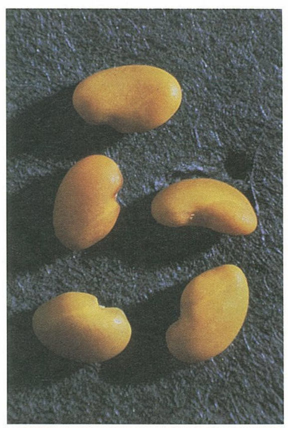


Fig. 2
Alfalfa seeds

Summary

Unlike grain crops, the value of alfalfa is based on the yield and value of the entire plant. Alfalfa yield, persistence, and, to some extent, quality have been improved through plant breeding. However, understanding how the alfalfa plant grows and develops will assist in managing to provide ideal growing conditions, which are essential if a producer is to capture the superior genetic potential of newer varieties.

Management Tips for Optimum Alfalfa Growth and Development

Select alfalfa varieties with proven high-yield potentials and persistence (disease resistance and winter hardiness) in your region.

Get the soil tested, then fertilize and lime according to the soil test recommendation.

Plant alfalfa in deep, well-drained fields.

Inoculate seed, plant $\leq 1/2$ inch deep at an adequate rate for your area, and insure good seed-to-soil contact for rapid germination and emergence.

Control diseases, insects, and weeds.

Apply needed nutrients annually, based on soil tests.

Follow a harvest schedule which meets forage-quality needs and leads to the desired life expectancy of the alfalfa stand.

The Certified Alfalfa Seed Council acknowledges and sincerely thanks the following for their contribution to "How an Alfalfa Plant Develops".

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Glossary

Apical meristem - the meristem at top of shoot or tip of root. The location where cells are produced that eventually become shoots, leaves, or buds.

Axil - the upper angle between a petiole of a leaf and the stem from which it grows.

Axillary bud - the bud formed in axil of a leaf.

Calyx - the modified leaf located at the base of the flower (also known as sepals).

Corolla - flower petals, consisting of banner, wing, and keel petals in alfalfa.

Contractile growth - growth in which the root cells contract vertically, pulling the cotyledonary nodes and their associated axillary buds below the soil surface to form the crown.

Cotyledons - structures in seeds that contain concentrated amounts of proteins, oils, and carbohydrates to be used as energy sources during germination and emergence.

Crown - the area at the base of the stem with tightly packed nodes and internodes, which generate vegetative growth. The formation of the crown results from contractile growth pulling axillary buds on the first branches of a seedling below the soil surface and is the potential area of meristematic activity.

Crown bud - the bud formed at the axillary site on the crown.

Epicotyl - the portion of the plant which is above the cotyledons.

Epigeal emergence - a type of emergence where the cotyledons are pulled above the soil surface.

Fertilization - the union between the pollen grain and the ovule.

Hilum - scar tissue on an alfalfa seed where the seed was attached to the pericarp (seed pod).

Hypocotyl - the portion of the plant which is below the cotyledons.

Leaf - the plant organ borne by the stem, responsible for photosynthesis and gas exchange; comprised of the petiole, leaflets, and stipule.

The Basics of Alfalfa Growth.

Alfalfa growth is driven by photosynthesis, a process that captures the sun's energy and converts it into chemical energy. Glucose sugar is the primary chemical energy product of photosynthesis. Glucose combines with other nutrient elements to provide all the components needed for alfalfa growth.

Alfalfa requires nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, iron, boron, manganese, zinc, copper, molybdenum, and a few other micronutrients for growth. These nutrients, along with water, are absorbed by the root from the soil. Part of the nitrogen needed for growth, however, is obtained from bacterial nitrogen fixation in the root nodules. The amount of nutrients available in soil varies with: fertilization, cropping history, and soil type, depth, temperature, pH, and moisture.

Plants use products of photosynthesis, nitrogen fixation, and root uptake to form cells, the primary building blocks of plants. Cells divide, enlarge, and develop into specialized cell types that have various functions in the plant. Cells that have similar functions are collectively known as tissue (e.g. phloem and xylem). Different types of tissue that have somewhat related functions are collectively referred to as anatomical regions of the plant (e.g. vascular region). Anatomical regions which are located near each other form the organs (e.g. stem, root, leaf) of the plant. Continuous cell division and the collective enlargement of individual cells account for plant growth.

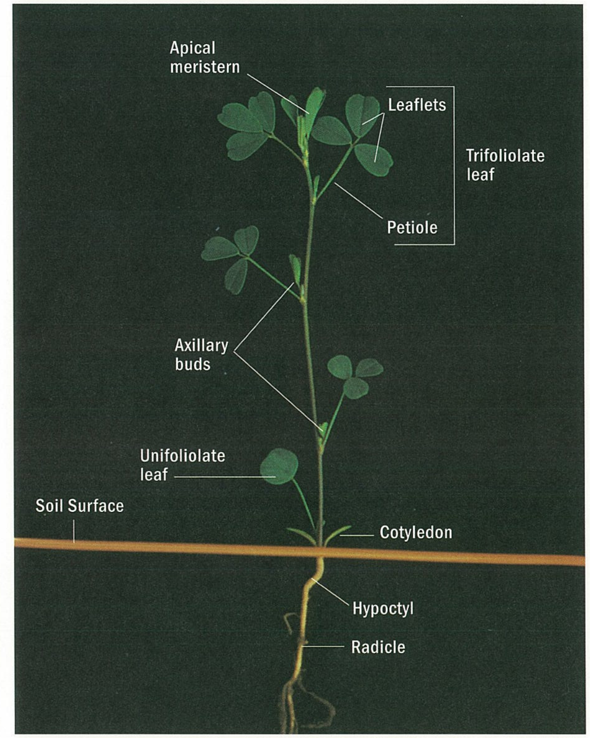
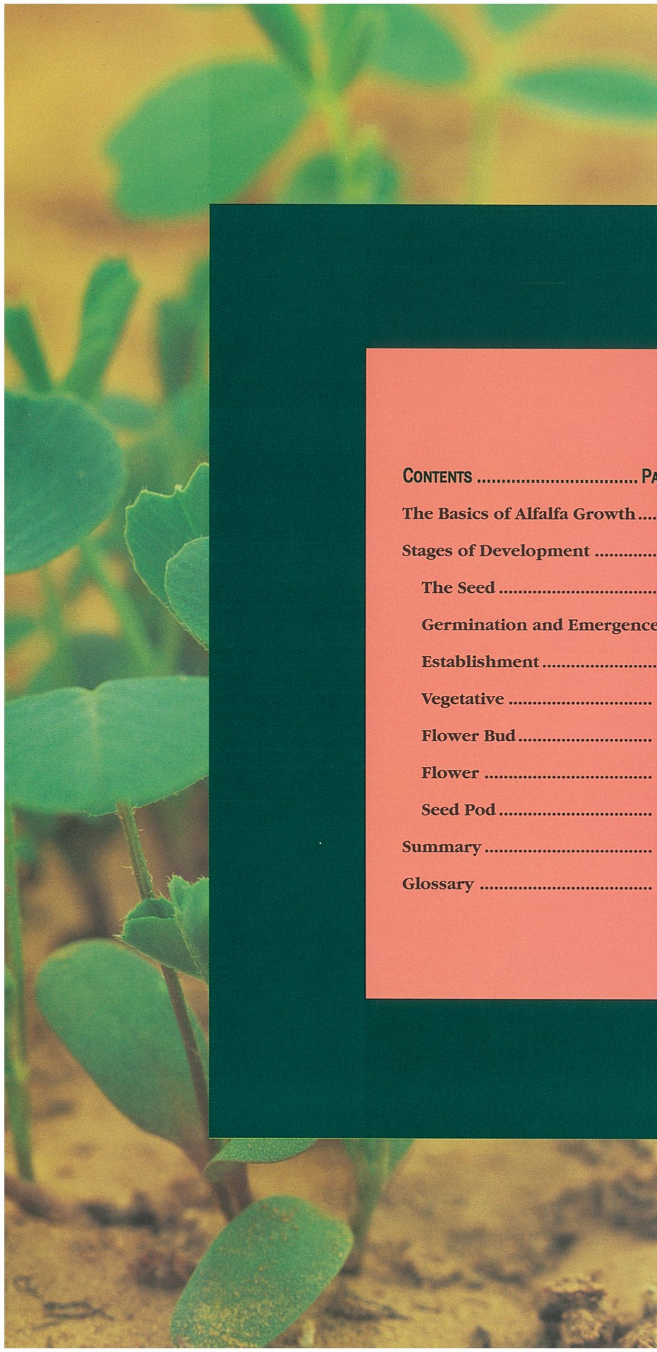


Fig. 1
Alfalfa seedling at the four trifolate leaf stage of development.



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This publication is designed to help those involved with production to better understand how the alfalfa plant develops. Combining a basic understanding of how alfalfa grows and develops with some applied management tips will hopefully result in improved alfalfa production through better management.

Meristem - the area of activity dividing cells; undifferentiated tissue capable of differentiating into specialized tissue.

Node - the location on the stem where the leaf attaches.

Nodule - the site of potential nitrogen fixation composed of a mass of root cells which surrounds the *Rhizobium* bacteria

Ovary - located at the base of the pistil which contains the ovules, this structure will become the seed pod (pericarp) in legumes.

Ovule - a rudimentary seed before fertilization; it contains the female egg cell.

Pedicel - a single branchlet which connects the flower bud, flower, or seed pod to the peduncle.

Peduncle - flower stem.

Pericarp - wall of the ovary (seed pod) which encloses seeds.

Pistil - the female portion of a flower, consisting of the ovary, style, and stigma.

Pollination - pollen coming in contact with the stigma.

Raceme - a type of flower where the floral structures are attached to the peduncle via a pedicel

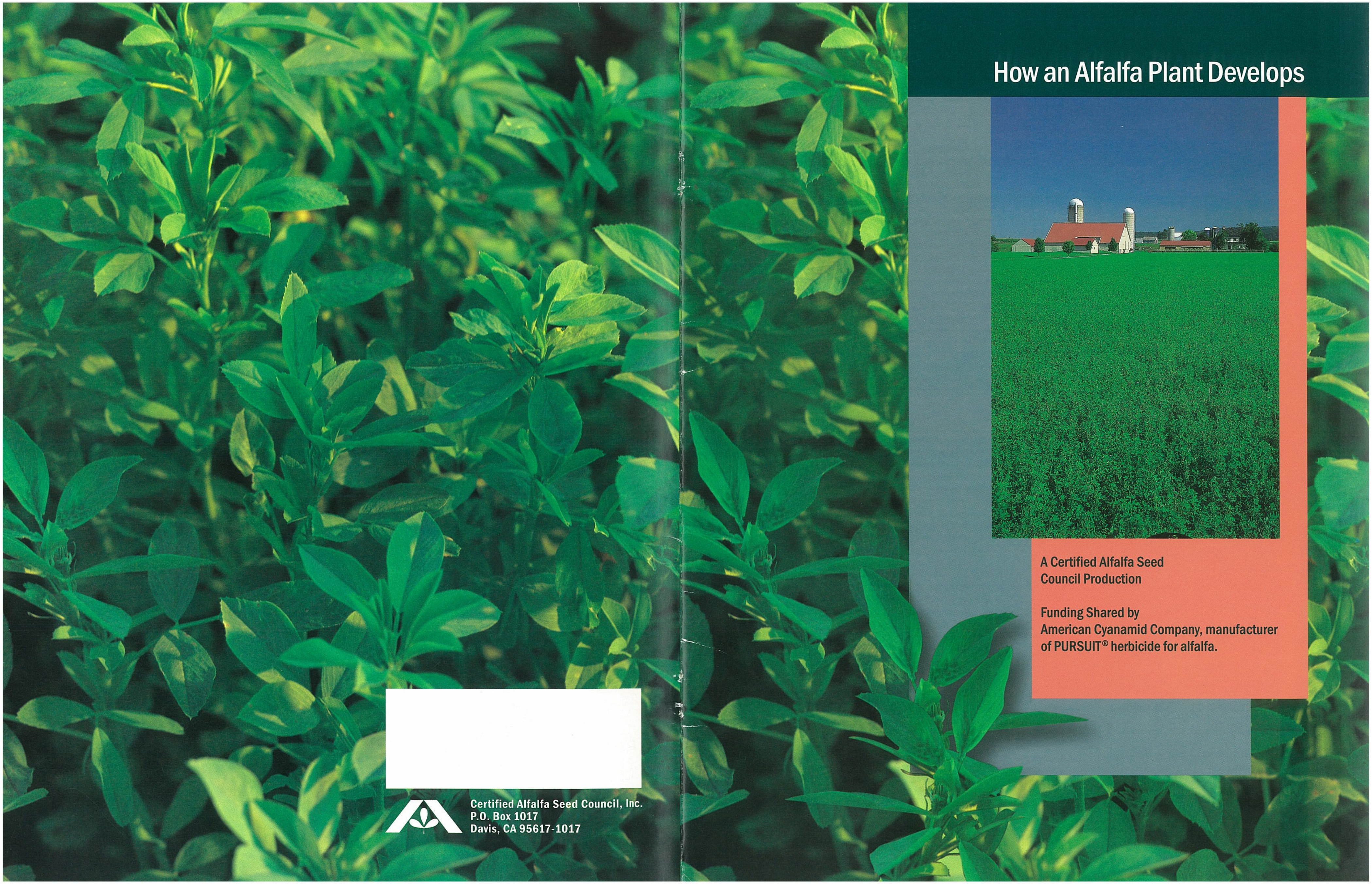
Regrowth - vegetative bud and shoot elongation either after the shoot is cut or after the shoot has attained sufficient maturity.

Rhizobium - bacteria responsible for nitrogen fixation in legumes.

Stamen - the male portion of the flower consisting of anther and filament.

Stem - aerial portion of plant with nodes and internodes.

Tripping - release of the pistil and stamen from the fused keel petals resulting in the rupture of the stigmata cuticle.



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A Certified Alfalfa Seed
Council Production

Funding Shared by
American Cyanamid Company, manufacturer
of PURSUIT® herbicide for alfalfa.

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