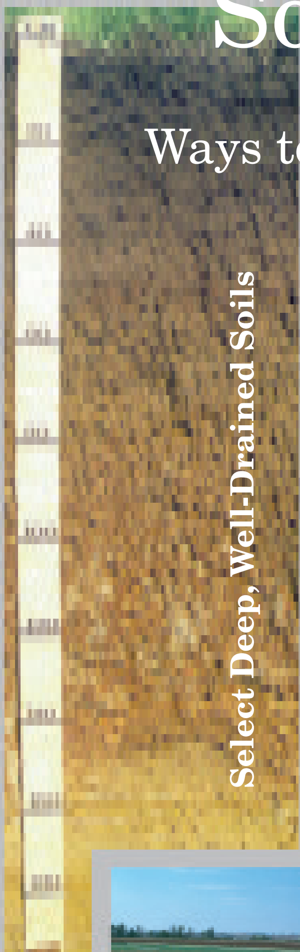
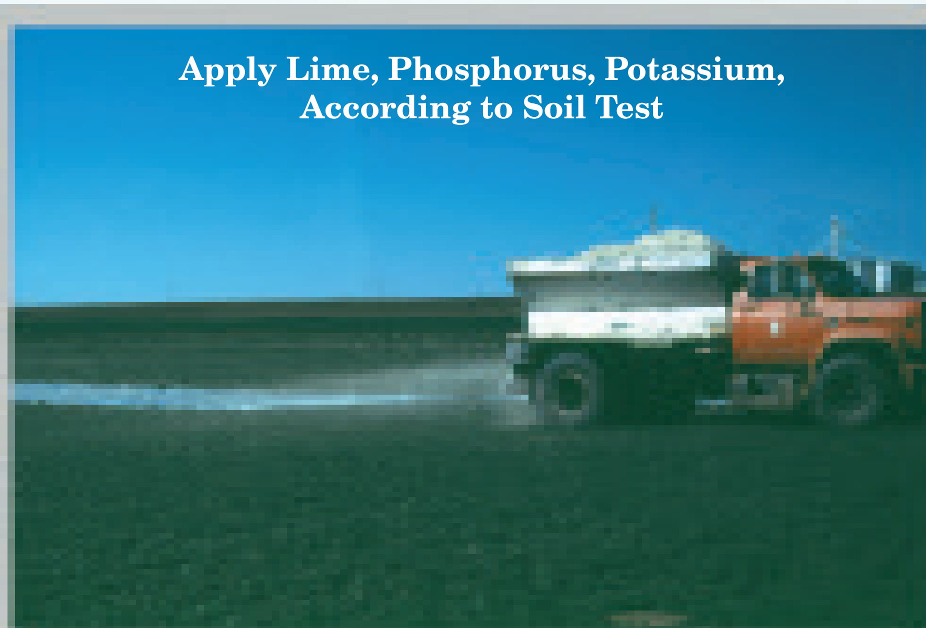
Alfalfa Production Guide for the Southern Great Plains

Ways to Improve Forage Yield, Stand Life, and Profits





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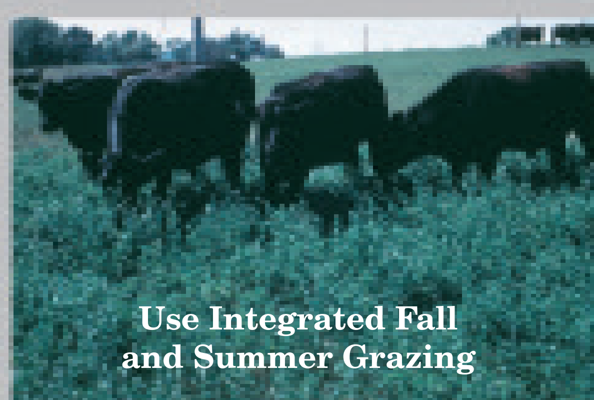

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Oklahoma Cooperative Extension Service ● Division of Agricultural Sciences and Natural Resources ● Oklahoma State University

Chapter 1
Introduction

Because of its importance among forage crops, alfalfa (*Medicago sativa* L.) is referred to as the "Queen of Forages." Lucerne is another name sometimes used for this species, which was first cultivated in Iran. Alfalfa was first successfully grown in the United States during the mid 1850s and is now most intensively grown in Wisconsin and other Upper Midwest states. The history of alfalfa in Oklahoma began with the first settlers. Many brought alfalfa seed from wherever they came, and descendants of some of those introductions are still grown by a few Oklahoma families.

During the last 25 years, alfalfa acreage has remained between 350,000 and 600,000 and is concentrated in the western half of the state. The cash value to Oklahoma rose from $74 million in 1977 to a high of $129 million in 1992. Part of this increase was due to average forage yields increasing from 3.2 to 3.6 tons per acre over this period. Higher hay prices also contributed — rising from $60 per ton in the late 1970s to more than $90 per ton during the 1990s.

Alfalfa is one of the most important forages for livestock. It is the most important high-quality forage crop because of its high protein, vitamins, energy, and digestibility. Alfalfa can be used whenever herbivores need a high-quality diet for:

- growth
- stamina
- strength
- production of meat, milk, wool, and eggs.

Alfalfa is used as a high-quality component of forage mixtures and allows use of lower-quality forages in rations. It is also important for soil enrichment, soil water holding capacity improvement, mulch, and extraction of deep minerals and nitrogen. It is even used by humans in nutritional tablets and health food!

Unique Characteristics

The combination of the following traits into a description for a single species adapted to widely diverse environments makes alfalfa unique. Important descriptors for alfalfa include:

- Herbaceous
- Legume
- Forage
- Quick regrowth capacity
- Nitrogen fixing
- Deep-rooted
- Resilient
- Heat and cold resistant
- Drought resistant
- Adversity avoider (dormancy)
- Leafy and palatable
- Highly digestible
- Nutritious
- Responsive to good management
- Storable as cubes, pellets, hay, or silage
- Utilized fresh for grazing, green chop, or green manure
- Competitive with weeds
- Reproduction by seeds, rhizomes, stolons, and cuttings
- Persistent perennial

Production Requirements

High-yielding alfalfa requires deep soils to store an abundant water supply for season-long growth. High yield requires large quantities of water (from rainfall, water table, or irrigation). Alfalfa requires approximately 6 inches of water in the root zone for each ton of hay produced per acre per year.

In addition, soils should have a pH near neutral (6.6-7.5) and be fertile enough to supply large quantities of nutrients. The benefits of having a desirable pH include:

- decreased solubility of toxic elements
- increased availability of essential nutrients
- increased activity of soil microorganisms
- better nitrogen fixation

Harvesting five tons of hay per acre removes approximately 50 pounds of phosphorus (P_20_5), 100 pounds of calcium, and 220 pounds of potassium (K_2O) from the soil. Eventually these nutrients must be replenished with fertilizer applications as indicated by a professional soil analysis.

All soil textures (sands, loams, and clays) can be used for alfalfa; however, soils should be well drained to avoid root and crown diseases and to allow oxygen flow to roots for nitrogen fixation by *Rhizobium* bacteria. Soils with pH near neutral favor nutrient availability and *Rhizobium* activity for good alfalfa production.

Chapter 2
Pests and Pest Management

Integrated Pest Management

Unlike annual crops in which vigor and productivity must be maintained for only one growing season lasting several months, alfalfa is a perennial forage legume that, once established, is typically expected to remain highly productive for 5-7 years. This expectation requires consideration of both short-term and long-term consequences of management decisions, especially those related to pest control. Effective pest control is possible only with a comprehensive integrated pest management (IPM) program that targets insect pests, weeds, and plant pathogens.

The ability of plants to survive stresses imposed by pest infestations depends greatly on the initial vigor of the stand at establishment. From the time that plants emerge, they are subjected to insect feeding, diseases, and competition with weeds. Alfalfa is quite attractive as a host for phytophagous insects. Species such as the alfalfa weevil and aphids may cause moderate to severe damage at any time during stand life (see "Insect Management" in this chapter). As alfalfa stands age, infections by several types of pathogens tend to become more prevalent. This is particularly true of soil-borne fungal pathogens such as *Phytophthora* sp. and *Fusarium* sp. (see "Alfalfa Disease" in this chapter). In addition, the incidence of soil-borne pathogens may be increased as a result of damage by insects. For example, damage by soil insects to the roots of alfalfa plants provides points of entry for fungi, leading to increased levels of infection. Finally, as alfalfa stand densities decline due to stresses imposed by insect pests and pathogens, weeds exploit bare soil areas, grow, and compete with alfalfa.

Neither weedy grasses nor broadleaf weeds survive and grow in healthy, full stands of alfalfa. Weeds can grow only after open spaces form in the alfalfa canopy as a result of stand decline. Typically, there is little weed growth in established stands until 3-5 years after establishment, when stand densities decline below 25 stems per square foot (see "Weed Management" later in this chapter). Once weeds have space to grow, they become competitive and are an important sign of stand decline. It is important, therefore, that insect populations are monitored and controlled in a timely manner every year in both full and thinning stands since alfalfa cannot compete with weeds if stressed from insects. Because the occurrence of different pests is often interrelated, staying focused on good pest management usually provides both immediate yield savings and long-term benefits through improved stand longevity.

Individual vs. Combined Effects

Field experiments have been conducted in central Oklahoma to determine individual and combined effects of foliar insect pests (alfalfa weevil, blue alfalfa aphid, spotted alfalfa aphid), and cool-season weeds (downy brome and shepherdspurse) on alfalfa. Beginning in the second stand-year, four levels of pest management were used (see Table 2-1 for treatments). The effect of controlling pests on seasonal yields — i.e., tons of alfalfa forage per acre (minus weed content) and stand densities in stems per square foot — were determined for five years (the second through sixth stand-years).

In the second stand-year, stem densities for the various levels of pest management were similar (30-32 stems per square foot), and no alfalfa yield reduction due to weeds was evident. There was a loss of 0.5 tons of alfalfa per acre in the 2nd year when insects were not controlled (Table 2-1). By the 4th stand-year, stem densities decreased to 25-26 stems per square foot, with no evidence of stand reduction due to pests.

Table 2-1. Effect of weed and insect stress on alfalfa hay yield and stem densities in 2nd, 4th, and 6th years of stand life

Weeds Sprayed	Insects Sprayed	Yield Reduction 2nd yr.	Yield Reduction 4th yr.	Yield Reduction 6th yr.	Stand Density 2nd yr.	Stand Density 4th yr.	Stand Density 6th yr.
		tons per acre			stems per sq. ft.		
Yes	Yes	—	—	—	32	26	16
No	Yes	0	0.2	2.1	30	25	13
Yes	No	0.5	0.5	2.3	31	26	11
No	No	0.5	0.8	4.5	31	26	9

However, in the fourth year, there were measurable alfalfa yield losses resulting from both weed and insect pests (0.2 and 0.5 tons per acre, respectively). By the sixth stand-year, average stem densities in plots where both weeds and foliar insects were controlled had declined to 16 stems per square foot. This stand decline over time was attributed primarily to infection by soil-borne fungi. (Note: Currently there is no fungicide labeled for control of diseases in established stands. Using disease resistant varieties is the only effective option.)

By the sixth stand-year, stress from insect pests and weeds reduced both stem densities and forage yield of alfalfa. When foliar insect pests and weeds were not controlled, stem density averaged just nine stems per square foot with a 4.5 ton per acre reduction in yield of alfalfa (Table 2-1). These results emphasize the need for integrated pest management programs that consider all types of pest infestations.

IPM Components

Establishment of a healthy stand with complete alfalfa ground cover is critical to pest management and to profitable hay production. The capability of alfalfa to withstand stresses imposed by pest infestations depends greatly on initial stand vigor. Soil testing should be conducted as land is prepared for planting so that the needed amounts of fertilizer and lime can be incorporated (see Chapter 4, "Fertilizing Alfalfa" for details). Following careful preparation of a firm seedbed (see Chapter 3, "Stand Establishment" for details), high- quality seed of a multiple-pest resistant variety should be planted. Perhaps the most important pest management decision to be made over the life of an alfalfa stand is to plant an improved, multiple-pest resistant variety selected from the list updated annually by Oklahoma Cooperative Extension Service specialists. Farmers should accept no substitute for the most recently recommended improved varieties with the highest available levels of resistance to insects and pathogens. In field experiments evaluating stand life and productivity, alfalfa forage yields in the sixth year averaged over six tons per acre for improved varieties compared to 2.2 tons per acre for the season with Oklahoma common, which has no pest resistance.

Timely grazing of alfalfa stands can provide cost effective means of reducing stress from insects. For a modest investment in labor and fencing materials, grazing in late winter through early spring (February through March) can greatly reduce populations of insect pests such as alfalfa weevil and aphids. Cleanly grazing stands in fall to early winter to remove dead foliar growth left from the previous season and new crown growth, consistently reduces populations of alfalfa weevil larvae and aphids. This type of grazing can reduce the number of insecticide applications required to keep the insects below economic threshold levels, or in some years, can eliminate the need to spray for insects. Returns from grazing include the value of forage consumed by livestock and savings resulting from reduced pesticide applications.

Early first harvesting can be a good alternative to spraying for control of alfalfa weevil larvae in some years. In most years egg hatch and larval development is completed by mid-April when alfalfa typically begins to bud in southern and central Oklahoma. Development of weevil infestations may be delayed enough that haying at early bud stage may be considered as an alternative to spraying. Haying early is most effective when weather remains warm and dry, promoting rapid drying of forage for baling. Such conditions also expose weevil larvae to the heat of the sun with little foliar growth for food or protection.

Pesticides are the only effective means of control available when insect pest populations exceed **economic threshold** levels and significant losses in productivity are likely to occur. The economic threshold level is reached when there is enough pest infestation that the **potential** loss from that infestation exceeds the cost of a chemical application. At this infestation level, spraying becomes profitable. Infestations of alfalfa weevil larvae or blue alfalfa aphids can reach economic thresholds in many fields in Oklahoma on an annual basis, particularly in those not cleanly grazed in winter or early spring. Thus, it is important that fields be scouted regularly during March and April and that timely applications of insecticide are made. It is critical that sprays be timed properly according to the "shake-bucket" method to attain maximum returns on investments for insecticides (see OSU Current Report No. 7177 for details). If sprays are applied too late (once extensive plant damage has occurred), significant losses of alfalfa yield will result. In addition, profitability of applying insecticides tends to decrease in mid-April since populations of insect pests are decreasing and activity of beneficial insects such as lady beetles and parasitic wasps is increasing.

Unlike annual problems with insect pests, weeds are not normally competitive with a full stand of alfalfa in the first 3-4 years of stand life. Herbicide treatments applied during this period usually provide no return on investment. Once stands begin to thin and weed production at first harvest is greater than 5 percent, it is important that cool-season weeds (downy brome, cheat, shepherdspurse) be controlled each year (see "Weed Management in Alfalfa" in this chapter). To maintain productive stands for 6-7 years, it is critical to plant an improved variety, maintain proper soil fertility, keep fields scouted for pests, and make timely applications of both insecticides and herbicides when needed.

Insect Management in Alfalfa

The most common insect pests in Oklahoma alfalfa include:

Alfalfa Weevil – the most damaging insect pest in late winter and early spring every year.

***Lygus* bugs** – the most damaging insect pest in alfalfa seed production.

Spotted Alfalfa Aphid – has great potential to cause stand loss in seedlings and established alfalfa.

Blue Alfalfa Aphid – a virulent biotype (BAOK90) has evolved that can cause severe damage in early spring.

Potato Leafhopper – commonly causes yellowing and severe stunting of alfalfa plants in summer.

Foliage-Feeding Caterpillars – always present during summer months.

As a perennial legume, alfalfa provides a favorable habitat and food source for a large number of insect species. Many of these species are considered pests because of injury resulting from their feeding on leaves, stems, and root systems of alfalfa plants. These insect pests of alfalfa are so varied in their life cycles and habits that feeding injury caused by one or more species may occur anytime throughout the entire year. Often, the damage resulting from feeding by insects threatens not only the yield or quality of a particular harvest of alfalfa, but may also result in thinning of stands and reduction in productive stand-life.

Fortunately, many beneficial insect species prey on plant feeders and help to

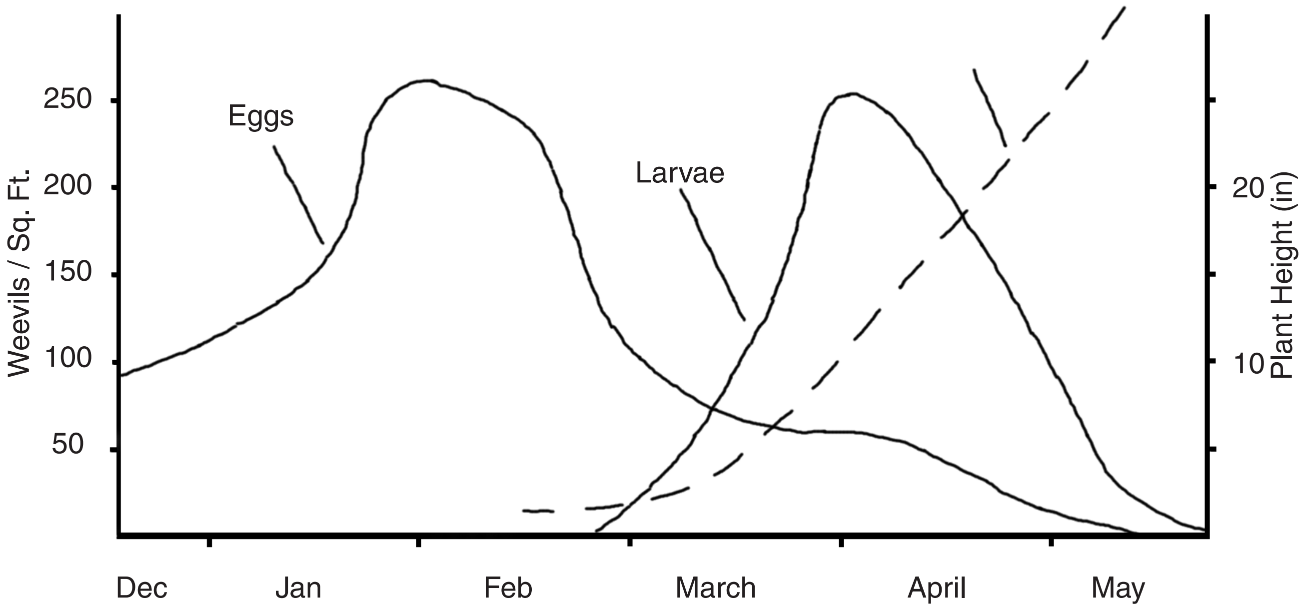

Figure 2-1 Graph of alfalfa weevil egg and larval occurrence

reduce their damage potential. Among these natural enemies are lady beetles, aphid lions, and other types of predators, as well as parasitic wasps and flies that attack foliage-feeding caterpillars and alfalfa weevils. Pollinators are another important group of beneficial insects essential to seed production in alfalfa.

This section of the manual provides descriptions of the various types of insects (both pests and beneficials) found in alfalfa, and outlines procedures for sampling to assess population densities. Additional information on insect life cycles, sampling procedures, photographs, and advisories related to current insect infestations can be obtained through the Oklahoma Alfalfa Calendar on the Internet at www.agr.okstate.edu/alfalfa.

Insect Pests in Alfalfa Forage Production

Alfalfa Weevil

Life Cycle and Damage. The alfalfa weevil is a snout beetle about 1/4 inch long, light brown with a dark brown mid-dorsal band (Plate 1). This insect completes one generation per year. The life cycle begins in late fall when adult weevils enter alfalfa fields from their summer resting sites (dense vegetation such as in fence rows and along creek bottoms). Adults normally begin laying eggs inside stems of alfalfa plants during November and continue until April or May of the following year. Egg lay (oviposition) continues throughout winter, and large numbers of eggs may accumulate before hatching begins during January or February. As they hatch, larvae leave the stems and crawl to growing alfalfa terminals to begin feeding. Newly hatched larvae are a yellow color and feed on developing leaf tissue within plant terminals (Plate 2). As they grow, larvae feed in more exposed locations on leaves and can be recognized by their green color and shiny black head capsules (Plates 3 and 4). Larval numbers usually increase rapidly as plant growth begins during February and March, and the potential for defoliation in early vegetative growth is great. The peak in larval numbers and greatest amount of damage occurs during March and April (Figure 2-1).

Yield reduction of alfalfa due to defoliation by weevil larvae is about 170 pounds per acre **in the first crop** for each increase of one larva per stem in the population. An additional reduction of about 140 pounds per acre occurs **in the second crop** due to loss of vigor in damaged alfalfa stands. With combined losses due to actual feeding damage in the first crop

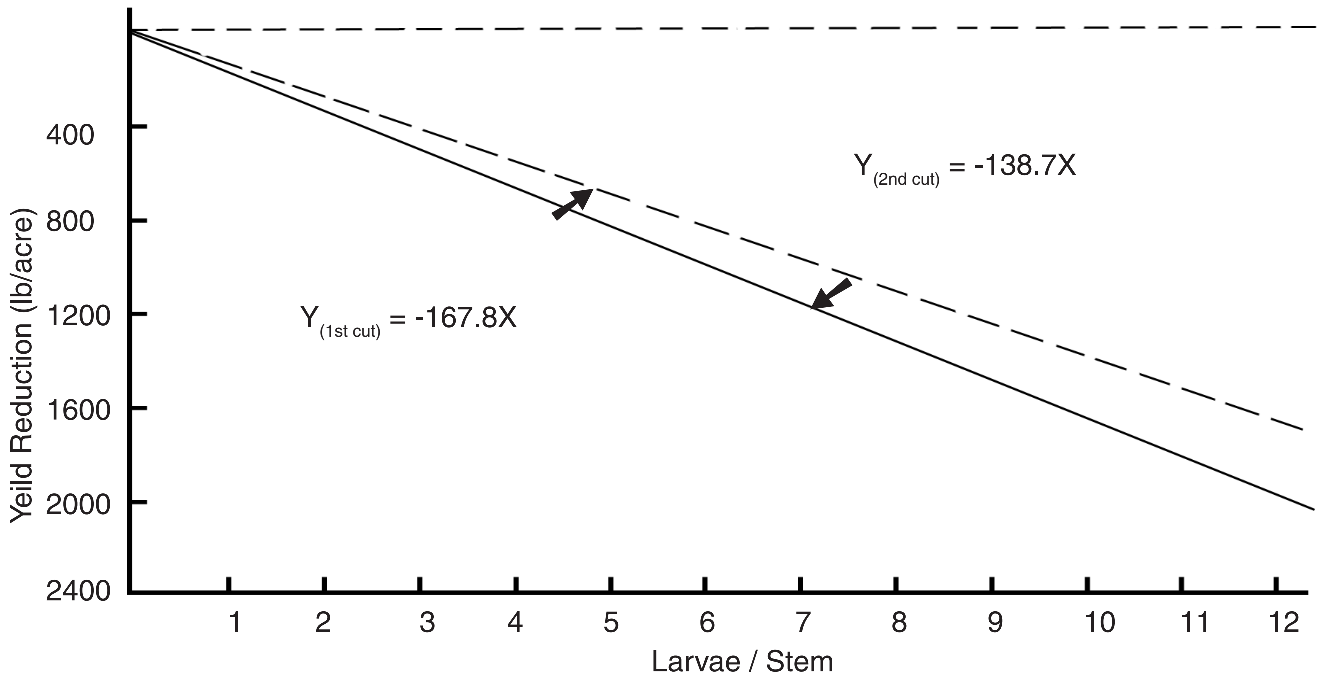

Figure 2-2 Graph of infestation vs. yield reduction

and residual effects later totaling more than 300 pounds per acre for each increase of one larva per stem, timely, effective insecticide applications are essential. Insecticide applications should be made when results of field scouting indicate that weevils are present in high numbers and **potential losses** due to feeding will exceed the cost of control (at the economic threshold). The time period when larval numbers exceed the economic threshold may vary greatly by year and location in Oklahoma, ranging from late February to mid-April.

Sampling and Control. The 'shake-bucket' scouting procedure is designed for use in decision-making relative to application of chemical insecticides and takes into consideration **1)** accumulated heat energy (degree-days) for weevil development, **2)** alfalfa plant height, and **3)** number of weevil larvae collected in a 30 stem sample (OSU Current Report No. 7177). Degree-day values for each county can be obtained from the Oklahoma Mesonet System (okmesonet.ocs.ou.edu). Specific values obtained for these three variables at the time of sampling are combined in a recommendation chart to determine if spraying is warranted. If spraying is not recommended on a particular sampling date, a time interval for resampling is given. This is the most accurate sampling procedure for decision-making, particularly when sampling after application of insecticide or following a period of freezing weather that may have killed some larvae.

When a recommendation to spray is indicated by the scouting process, it is important to follow label instructions for rates of insecticides to apply. Applications should be made with favorable weather conditions: temperature above 50°F and wind velocity less than 10 mph. For both ground sprayers and aerial application, swath width should not exceed the length of the spray boom to avoid skips in coverage. For effective control of weevil larvae, it is important that adequate spray volume is used for thorough coverage of alfalfa foliage; a minimum of 10 gallons per acre with conventional ground equipment and 2-4 gallons per acre for aerial application is recommended. The value of increasing spray volume for effective control of the alfalfa weevil is illustrated in Table 2-2.

Application of insecticides has been an essential component of control programs for the alfalfa weevil in Oklahoma since 1970. Nevertheless, populations of this pest and the potential for losses can be reduced by other means such as planting varieties with tolerance to insects and by grazing of alfalfa stands for 2-3 weeks during December and January. Grazing can reduce number of alfalfa weevil eggs in March by 50-70 percent (compared to nongrazed). Recent studies have also shown that grazing during March can remove nearly all eggs and larvae present and eliminate the need for spraying. Grazing in March, however, is usually not recommended in hay fields due to bloat and increased weed problems (see "Integrate Grazing into Harvest of Thinning Stands" in the Weeds Management section of this chapter).

Two natural enemies of the alfalfa weevil are wasps that parasitize weevil larvae and a fungal disease that kills both larvae and pupae. These beneficials are most important for killing weevils remaining in stands near the time of first cutting. The fact that weed growth is increased in areas that are defoliated gives an added incentive for maintaining an effective control program for the alfalfa weevil. Additional information relating to control of the alfalfa weevil can be found in OSU Extension Facts F-2097 and at www.agr.okstate.edu/alfalfa.

Table 2-2. Effects of increasing spray volume for control of alfalfa weevil with aerial application

Spray Volume	Days after Application		
	3	7	14
gal./acre	— weevil larvae per stem —		
0.5	1.5	1.6	3.0
1.0	1.0	1.4	2.2
2.0	0.9	1.1	2.4
4.0	0.8	0.8	1.9
Unsprayed	3.0	3.8	9.9

Alfalfa Aphids

Species Identification. Although aphid infestations can occur at nearly any time of the year in Oklahoma, damaging populations are most common from February to May during growth of the first alfalfa crop. Two species usually found during this time each year are the **pea aphid** and **blue alfalfa aphid**. The pea aphid is the largest of the species found in alfalfa, and is typically a light green color (Plate 5). This species prefers to feed on stems and developing leaves near plant terminals. Blue alfalfa aphids are somewhat more blue-green in color and are typically smaller than pea aphids. Preferred feeding sites are similar to those of the pea aphid, except that the most common biotype of the blue aphid in Oklahoma (designated BAOK90) may be found in greatest numbers on lower portions of stems. The most reliable way to distinguish pea aphids and blue alfalfa aphids is by careful examination of the antennae. Using a hand lens or magnifying glass (10X), dark-colored rings can be seen at regular intervals on antennae of pea aphids (Plate 5), while those of blue aphids have no dark rings, but rather become gradually darker in color near the tip (Plate 6). Pea aphids and blue alfalfa aphids are adapted to relatively cool temperatures, and populations seldom persist beyond early July in Oklahoma.

A third species, the **spotted alfalfa aphid**, may infest alfalfa fields during February and March, but the occurrence of damaging populations in winter is relatively infrequent (5-10 year intervals). Infestations of spotted aphids are found commonly during warm, dry weather, typical of late summer and fall in Oklahoma. Size of this species is relatively small in comparison to the pea aphid or blue aphid. Its color ranges from light green to tan with several rows of dark spots (Plate 7). Spotted alfalfa aphids may be found in greatest numbers on leaves and stems in the lower portion of the plant canopy, near the soil surface.

An additional species that typically occurs in low numbers during late winter and spring is the **cowpea aphid**. This species ranges from gray to shiny black in color. The cowpea aphid prefers to feed on leaves near plant terminals and on stems. Interest has increased regarding this species as it has been found in relatively large numbers throughout the summer months since 1999.

Damage Caused by Aphids. All aphids feed by removing fluid from plants with piercing-sucking mouthparts. When large numbers of aphids are present, their feeding typically results in wilting of foliage and stunting of plant growth. Often, feeding causes leaves to become chlorotic, having a yellow discoloration. Of the four species found in alfalfa, the symptoms observed with infestation by the **cowpea aphid** have been the least severe. There has been little evidence of necrosis (death of leaf tissues) and no mortality of plants observed with feeding by this species. It is important to note, nonetheless, that seasonal occurrence of the cowpea aphid has changed radically in recent years, with high population densities occurring during summer months. It is unclear at this time if damage potential from this insect will increase and warrant spraying in the future.

In the presence of high population densities, feeding by the **pea aphid** typically results in stunting of plant growth and chlorosis of leaves. Only with large numbers and an extended period of infestation does wilting of plants with necrosis of leaf tissues occur. There is little threat of stand loss due to damage by pea aphids. From the time data were first collected in Oklahoma in 1977 until 1990, the extent of damage by the **blue alfalfa aphid** was similar to that of the pea aphid. High population densities resulted in deformation of leaves near plant terminals and moderate to severe stunting of plant growth. There were few reports of stand reductions due to blue aphid infestation. Since 1990, however, a virulent biotype (BAOK90) has been identified with the potential to cause death of plants and severe stand reduction. This biotype induces a severe toxic reaction in alfalfa plants, with symptoms that typically include stunting and death of plants during relatively short periods of infestation (2-3 weeks).

Until 1990 and the identification of blue aphid biotype BAOK90, the **spotted alfalfa aphid** clearly had the greatest damage potential of any insect pest in alfalfa. This species induces a severe toxic reaction in susceptible alfalfa plants that results in chlorosis and necrosis of leaves, beginning in the lower portions of the plant canopy. An unusual damage symptom often caused by the spotted aphid is clearing of veins of newly-formed leaves near plant terminals, which is called "veinbanding" (Plate 8). Heavily infested plants are killed within 1-2 weeks, and stand loss may be severe, particularly in those infrequent years when infestations occur in late winter and spring at a time when there is relatively little foliar growth. The spotted aphid is a serious threat to newly planted stands because its seasonal abundance is greatest from August to October when alfalfa is planted. The threat of stand loss due to this species is great in newly planted alfalfa because seedlings, even those of resistant cultivars, may have limited ability to withstand feeding.

Sampling and Control. Aphid numbers may be estimated by sweepnet sampling, by pulling samples of stems, or by pulling whole plants in seedling stands. Examining whole seedling plants is the only effective option for newly planted stands and for stands where foliar growth is less than eight inches tall. Sampling should be done at least once per week following emergence of seedlings in new stands of alfalfa and during growth of the first crop in established stands as numbers of aphids may increase quite rapidly during optimal weather conditions. Sampling may be conducted less frequently during summer months, unless infestations of spotted alfalfa aphids have been detected, in which case weekly sampling should be continued.

For sweepnet sampling of aphids, use a 15-inch diameter net with a heavy muslin bag. Take 20 sweeps at each of a minimum of five locations per field. For each location, place contents of the net in a pan and estimate the numbers of aphids of each species present. Determine average population densities for each species in the field and refer to Table 2-3 for treatment guidelines. Numbers of predators such as ladybird beetles (Plates 9 and 10) and aphid lions (Plate 11) should also be counted. If aphid counts are below the economic threshold and numbers of predators exceed 5-7 per sweep, aphids may be controlled by the predators.

For stem or seedling plant sampling, a sample of 30 stems or seedlings should be collected at random in each 10-20 acre area and aphids shaken into a container for counting. Divide aphid numbers of each species by 30 to calculate the average number per stem. Estimate plant height, and refer to Table 2-3 for treatment guidelines.

The most important factor for effective aphid management in alfalfa is variety choice. All improved varieties recommended for production in Oklahoma have resistance to one or more of the aphid pests discussed. Most have high levels of resistance to pea aphid and spotted alfalfa aphid. Although the virulent biotype of blue aphid is adapted to most resistant cultivars, new variety releases are being made with resistance to biotype BAOK90. For a modest increase in seed cost for improved varieties compared to Oklahoma common alfalfa, a high degree of protection against aphid losses can be obtained for the life of a stand. It is an investment that is well worth the cost.

Several types of predators including lady beetles, aphid lions, and damsel bugs assist in limiting aphid populations in alfalfa. As indicated earlier, when relatively large numbers of predators are present and aphid populations have not reached the economic threshold, natural control agents usually provide effective regulation of aphids. Parasitic wasps may be important in limiting population growth of spotted alfalfa aphids during summer months. In order to preserve these beneficial species, proper sampling and comparison of aphid population densities with economic threshold levels should be done before insecticide applications are made. Additional information relating to control of aphids can be found in OSU Extension Facts F-7184 and at www.agr.okstate.edu/alfalfa.

Cutworms

Life Cycle and Damage. Species that commonly infest alfalfa include the **army cutworm** and the **variegated cutworm**. Although damage by these species may be quite severe, high population densities are relatively infrequent, typically once every 6-8 years. Damage from cutworm larvae typically occurs at consistent times during the year and usually results from a single generation per year for each species. Army cutworm adults (moths) lay eggs during October in newly planted or cleanly harvested fields. Eggs hatch during the fall, and the small larvae overwinter. Most feeding by these larvae occurs as weather warms in March. Army cutworm larvae are gray to tan in color and finely mottled with white and brown, but without prominent markings (Plate 12). Fully grown larvae may attain a length of 2 inches. When present in large numbers, army cutworms consume all crown growth of alfalfa and may delay spring "green-up" by 4-6 weeks (Plate 13).

The variegated cutworm overwinters in the pupal stage, and adults emerge to mate and lay eggs during growth of the first crop of alfalfa in April. Eggs hatch and larvae begin to feed on leaves in the lower portion of the foliar canopy before the first harvest. Larvae are gray to black in color with distinctive white

Table 2-3. Economic thresholds for aphids on alfalfa at varied growth stages

Growth Stage	Cowpea Aphids per		Pea Aphid per		Blue Aphids per		Spotted Aphids per	
	sweep	stem	sweep	stem	sweep	stem	sweep	stem
Seedling	- -	5	- -	5	- -	1	- -	1
<10 inches tall	300	40	300	40	100	10	100	10
>10 inches tall	400	75	400	75	200	30	200	30

to yellow diamond-shaped markings along the center of the back (Plate 14). The most serious threat of damage occurs on regrowth following the first harvest of the year (usually early May). Variegated cutworms feed primarily at night and tend to seek protected habitats within plant foliage or debris during daylight. They aggregate beneath windrows when hay is cut, and the greatest damage to regrowth is often where windrows have lain in fields. There is frequently a ribbon-like appearance of alternating heavy damage (under windrows) and light damage (between windrows) in infested fields after baling (Plate 15).

Sampling and Control. Detection of cutworms and assessment of population densities is often difficult because of their nocturnal feeding habits. Whenever alfalfa seems slow to green up during March or after first harvest, fields should be checked for the presence of cutworms. Sampling requires sifting through plant debris and the upper inch or two of soil around plants. A minimum of 10 one-square-foot areas should be sampled in each 10-20 acre field area. When numbers of small larvae (up to 1/2-inch long) exceed an average of three per square foot, an insecticide should be applied. If large larvae (>1/2-inch long) are present, spraying is recommended when numbers exceed two per square foot. Control of cutworms with insecticides may be difficult. It is important that applications be made in late afternoon or evening, near the time when larvae begin to feed, using high spray volumes (10 gallons per acre for ground application and 2-4 gallons per acre for aerial application) to ensure thorough coverage. Additional information on control of cutworms can be found in OSU Extension Facts F-7150 and at www.agr.okstate.edu/alfalfa.

Foliage-Feeding Caterpillars

Life Cycle and Damage. The larval stages or "caterpillars" of several species of butterflies and moths are common foliage feeders in alfalfa from May through October. The most important of these are the **corn earworm** (Plate 16), **yellow-striped armyworm** (Plate 17), **fall armyworm** (Plate 18), **alfalfa caterpillar** (Plate 19), **green cloverworm** (Plate 20), and **forage looper** (Plate 21). Each of these species completes several generations during summer and fall, with each one lasting 4-5 weeks. When present in large numbers, these caterpillars may completely defoliate alfalfa, consuming the leaves for their high nutrient content and leaving only the stems, which have limited value as livestock feed.

Sampling and Control. The most effective sampling approach for these caterpillars is sweeping with a standard 15-inch diameter net. A set of 20 sweeps should be made in each 5-10 acre field area. If numbers exceed six larvae per sweep, insecticide should be applied, or if the time for harvest is near, alfalfa may be cut to remove the caterpillars' habitat. Additional information on control of foliage-feeding caterpillars can be found in OSU Extension Facts F-7150 and at www.agr.okstate.edu/alfalfa.

Potato Leafhopper

Life Cycle and Damage. This small wedge-shaped insect is light green and about 1/8-inch long (Plate 22). This species does not overwinter in Oklahoma, but migrates northward from coastal areas of the Gulf of Mexico on storm fronts each spring and is usually first collected in May. The most characteristic symptom of damage by the leafhopper is chlorosis and eventual necrosis of tissues at leaf tips, called "hopperburn" (Plate 22). In addition, growth of alfalfa plants may be severely stunted, resulting in both quality and yield reductions.

Sampling and Control. The primary means for sampling to assess the need for control of leafhoppers is sweepnet sampling. At least five sets of 20 sweeps should be taken in each field up to 40 acres. More samples should be taken in larger fields. The greatest potential for losses due to potato leafhopper occurs with infestations on new growth after a harvest has been taken. Although sweeping is difficult in alfalfa stubble, the effort should be made because the economic threshold in six inch or shorter alfalfa is an average of 0.5 leafhoppers per sweep. When alfalfa is 12 inches or taller, the threshold is two leafhoppers per sweep. When growing conditions are optimal for alfalfa, applying insecticide when these thresholds are reached can be profitable. However, when exceedingly dry conditions prevail, as often occurs in mid-summer in Oklahoma, the limited potential for alfalfa growth may not warrant an added expenditure for insecticide.

Leafhoppers survive from one flush of growth to the next by living on stems that were missed by the harvester. Making sure that all standing alfalfa in a field is cut can help control this pest. Additional information relating to control of leafhoppers can be found in OSU Extension Facts F-7150 and at www.agr.okstate.edu/alfalfa.

Blister Beetles

Life Cycle and Damage. Several species of blister beetles are common throughout eastern and southern areas of the U.S., and in no way is the problem with blister beetles in alfalfa restricted to Oklahoma. The species found in alfalfa range in color from a uniform black or gray to a striped pattern of alternating brown and orange. It is the **striped blister beetle** that most commonly forms large aggregates or "swarms" in alfalfa fields (Plate 23). The blister beetles found in alfalfa complete one generation per year, which begins during late summer as females lay eggs in cracks and cavities at the soil surface. Eggs hatch and tiny long-legged larvae called "triungulins" crawl over the soil surface in search of clusters (or pods) of grasshopper eggs, which are also laid within 1-2 inches of the soil surface. Upon finding a site where grasshopper eggs have been laid, each triungulin tunnels into an egg pod and begins to feed. The larva continues to grow and develop while consuming the grasshopper eggs, then overwinters in the soil and emerges as an adult beetle the following May or June.

These beetles feed on foliage and blooms of many plants including alfalfa. However, it is not their feeding activity that gives them pest status, but the fact that the beetles contain a chemical called "cantharidin," a blistering agent that is highly toxic and may cause illness or death in livestock, particularly horses, when consumed in forage. Cantharidin is a highly stable chemical that remains active even within the dried remains of beetles. If the beetles are killed during alfalfa harvesting, as would occur when a crimper-conditioner is used for swathing, they may be baled into hay and inadvertently fed to livestock. In the case of the striped blister beetle that frequently forms "swarms" in alfalfa fields, remains of many beetles may be found in baled hay if they are killed at the time of cutting either by crimping hay or by wheel traffic over windrows. If they are not killed when alfalfa is cut, the beetles leave the windrows as the hay dries before baling, and the threat of cantharidin toxicity is eliminated.

All cases of mortality in horses resulting from cantharidin toxicosis that have been confirmed by the Oklahoma State University College of Veterinary Medicine have involved the striped blister beetle. Cantharidin toxicosis causes ulceration of sensitive skin areas (lip, nose, and mouth) and mucous membranes (esophagus and stomach). Severity of toxicosis symptoms depends primarily on the number of beetles consumed. Cantharidin is highly damaging to tissues of the digestive and urinary tracts. If large amounts of cantharidin are ingested, death may occur within six hours. When smaller amounts are consumed, horses may display symptoms of colic (pawing and stretching). Due to reduced levels of electrolytes (calcium and magnesium) in the blood stream, animals may exhibit stiffness or an exaggerated "goose-stepping" gait. Small amounts of darkened urine (blood in urine) may be voided as a result of damage to the kidneys and bladder. Horses displaying these symptoms should be promptly examined by a veterinarian, and hay should be examined for the presence of blister beetle remains.

Sampling and Control. There is no way to guarantee that alfalfa hay harvested in the southern United States is completely free of blister beetle contamination. However, several precautions can be taken to greatly reduce the chances that hay will be contaminated:

- Use hay harvested before mid-May or after early September as forage for horses. Chances of blister beetles being present at harvest are greatly reduced at these times.
- Scout fields beginning in border areas to look for swarms of blister beetles. Often they will be found within 50 to 100 yards of the field edge, but can occur anywhere in fields. If swarms are found, a short residual insecticide should be applied before cutting.
- Do not use a crimper when cutting hay intended for horses, especially during mid-summer when beetles are found most commonly. Avoid driving over windrows.
- Cut alfalfa in the bud stage; the presence of blooms is attractive to blister beetles and increases the likelihood of infestations.
- When small amounts of hay are being handled, as when feeding small square bales, examine hay carefully as it is fed to detect the presence of blister beetle bodies or body parts.

As there is no way to completely eliminate the threat of blister beetles in alfalfa, the prudent approach for management is to take all possible precautions to reduce the likelihood that they are present, particularly when marketing hay to horse owners. Additional information on blister beetles in alfalfa can be obtained from OSU Extension Facts F-2072 and at www.agr.okstate.edu/alfalfa.

Insect Pests in Alfalfa Grown for Seed

Some species described as pests in forage production may also interfere with profitable alfalfa seed production. When growing alfalfa for seed, it is important to scout fields before bloom to prevent stunting or defoliation of plants due to aphids, leafhoppers, and foliage-feeding caterpillars. Profitable seed production depends on healthy, vigorous plants that have not been subjected to stress during vegetative growth. To the greatest extent possible, use of insecticides must be avoided once pollinators (bees) have begun to work. Insect pests included in this section on seed production are those having the greatest potential to cause injury or destruction of buds, blossoms, or seeds.

Grasshoppers

Life Cycle and Damage. Grasshopper species that damage field crops such as alfalfa typically complete one generation per year. In Oklahoma, three of the most common species are the **differential** (Plate 24), **two-striped** (Plate 25), and **red-legged** grasshoppers. These grasshoppers overwinter as eggs laid in soil, usually along fences, roadsides, and in pastures rather than in field crops. Nymphs hatch from these eggs in late spring (May and June) and feed on grasses and broadleaf weeds outside of fields until mid-summer. When they have become large nymphs or adults and plants in non-cropland areas typically mature and become less palatable, grasshoppers then begin migrating into adjacent fields. Depending upon population densities, they may feed extensively on alfalfa or other available crops. Although grasshoppers may defoliate alfalfa in areas near field borders, they pose a much more serious problem in seed production because they often feed primarily on the fruiting structures when alfalfa is in bloom, causing nearly 100 percent loss of the seed crop near field margins.

Sampling and Control. Grasshopper population densities are typically estimated while walking in areas near field margins. As grasshoppers fly out of foliage, numbers per square yard are estimated. After alfalfa begins flowering, the economic threshold of 15-20 insects per square yard for alfalfa forage production does not apply to seed production because this infestation level may result in seed losses greatly exceeding the cost of control, and because insecticides and application rates sufficient to reduce grasshopper populations may be quite damaging to pollinators. It is critical that grasshoppers be controlled in nearby fence rows, pastures, and other adjacent areas before migration into alfalfa begins. Controlling grasshoppers in areas adjacent to fields in June is effective since hoppers are sprayed while they are small nymphs. Applications made at this time may prevent serious losses in seed production later and also preserve pollinators. Additional information on control of grasshoppers can be found in OSU Extension Facts F-7150 and at www.agr.okstate.edu/alfalfa.

Plant Bugs

Life Cycle and Damage. Although there are numerous species of plant bugs found in alfalfa, those that pose the greatest threat to seed production, such as the tarnished plant bug, are classified in the genus *Lygus* and are usually referred to as ***Lygus*** bugs (Plate 26). Nymphs of the *Lygus* bugs are a light green and are often mistakenly identified as aphids. However, they are much more active than aphids, often crawling rapidly over the plant foliage. Adults are yellow to brown in color and typically about 1/4-inch long. These insects overwinter as adults in alfalfa fields or adjacent areas with abundant grasses and weeds, which provide a protective habitat. *Lygus* bugs complete several generations per year and may be present in large numbers in summer months. Nymphs and adult *Lygus* bugs feed with piercing-sucking mouthparts to remove plant fluids from buds, blossoms, and green seed pods, causing these structures to die and drop from plants. In the presence of high population densities of *Lygus* bugs, seed set and maturation may be reduced by nearly 100 percent. Much of the flower drop in alfalfa seed fields that is often attributed to dry weather may in fact be due to feeding by *Lygus* bugs.

Sampling and Control. Fields where seed production is planned should be sampled by sweeping before bloom so that, if necessary, controls may be applied before pollinators are present. As *Lygus* bugs are flying insects and may migrate into fields in large numbers within short time spans, it is important that sampling be conducted as alfalfa enters the bud stage. At least five samples of five sweeps each should be taken in each 30-acre area of alfalfa. Spraying is recommended when there are an average of two *Lygus* bugs per sweep. Spraying after the onset of blooming is not recommended as it may kill pollinators. However, if large numbers of these insects have migrated into seed production fields after bloom has begun, it may be necessary to apply insecticide. If bee colonies have been placed in the field for pollination, they must be removed before spraying. Spraying should be done in late evening or early morning when pollinators are not active. Additional information on control of *Lygus* bugs can be found in OSU Extension Facts F-7150 and at www.agr.okstate.edu/alfalfa.

Webworms

Life Cycle and Damage. Webworms are larvae of small moths that complete several generations per year and often become quite abundant in alfalfa during summer months. When fully grown, these worms are about 3/4-inch long and have light green coloration with numerous black spots. As they develop, webworms spin silken webs over plant terminals, then feed on leaves, buds, and blossoms within the webs (Plate 27). Although extensive defoliation may not result from their feeding, webworms often consume fruiting structures, and their webs interfere with pollination and seed set. Infestations by these worms can result in serious losses in seed production.

Sampling and Control. As with other pests that have been discussed, it is important to assess population densities of webworms before alfalfa begins to bloom. Webworms can be counted in sweep samples taken for foliage-feeding caterpillars (20 sweeps in each of five areas per field). If the numbers of webworms exceed five per sweep (even in the absence of other foliage feeders) and silken webs cover 10 percent or more of the terminals, application of insecticide should be considered to prevent serious losses in seed production. It is important to use relatively high spray volumes (10 gallons per acre for ground application and 2-4 gallons per acre for aerial) to penetrate webs for effective control. Additional information on control of webworms can be found in OSU Extension Facts F-7150.

Alfalfa Seed Chalcid

Life Cycle and Damage. The adult of this species is a tiny black wasp (Plate 28; 1/10-inch long) that lays eggs in developing alfalfa seeds within green pods. A single larva develops within each seed, destroying all contents, then enters a pupal stage (Plates 29-30). Upon emergence from the pupal stage, adults chew holes in seed coats and seed pods to escape and lay eggs for a new generation. Several generations are completed each year, with increasing population densities and greater potential for damage through mid- and late summer. Larval and pupal stages of the fall generation overwinter in seed to emerge as adults the following spring. Surveys of damage in seed produced in Oklahoma have shown up to 80 percent loss due to the seed chalcid, with an average loss of 10-15 percent.

Sampling and Control. Seed chalcids cannot be controlled effectively with chemical insecticides, and spray applications made during bloom and seed set may cause high levels of mortality to pollinators. Thus, the primary means for limiting infestations is reduction of populations entering seed production fields through sanitation. Methods of sanitation include:

- Elimination of volunteer alfalfa along fence rows and roadsides by mowing or spraying with herbicides. The primary source of host plants for the chalcid in spring and early summer is volunteer alfalfa.
- Careful harvesting to avoid spilled seed that can serve as overwintering sites for chalcids.
- Not storing uncleaned seed through the winter as it may be infested with chalcids.
- Schedule seed production to complete harvesting by mid-August to avoid the time in late summer when the highest populations of chalcids are present.

Additional information on alfalfa seed chalcids can be found at www.agr.okstate.edu/alfalfa.

Beneficial Insect Species

It is fortunate for alfalfa growers that many of the insects found in this crop are natural enemies that attack the plant-feeding insect species. Although natural enemies do not typically maintain populations of some insect pests, such as the alfalfa weevil, below economic threshold levels, others such as aphids and foliage-feeding caterpillars are effectively controlled in most years. The need for insecticide applications would be increased greatly were it not for the presence of these natural enemies. A second group of beneficial insects that is of critical importance in alfalfa seed production is the pollinators. Without pollination by several species of bees, seed production in alfalfa is not profitable. (More on pollinators later in this chapter.)

Predators of Insects

The most well known among the predators are the **ladybird beetles**, a group in which both larvae and adults prey on a variety of insects, most commonly on aphids and small stages of foliage-feeding caterpillars. They also eat larvae of the alfalfa weevil. Species that are most common in alfalfa have an oval body shape and are usually bright orange and black (Plate 9). Among them is an imported species called "C-7," or the seven spotted lady beetle, which has become abundant throughout

Oklahoma. The larvae of lady beetles typically have elongated bodies with long legs and orange and black mottled coloration (Plate 10). Laboratory studies have shown that individual lady beetle adults and larvae consume 20-30 aphids per day.

Also common in alfalfa are the **aphid lions,** or larvae of the **lacewings**. Aphid lions resemble tiny alligators with long, curved, hollow jaws that they use to clamp onto insect hosts and suck out body fluids (Plate 11). These predators readily attack not only aphids, but foliage-feeding caterpillars as well. Adult lacewings are typically brown or green, with large, fragile wings (Plate 31).

The **damsel bugs** are slender-bodied insects with gray to tan coloration (Plate 32). Their front legs are adapted for grasping prey, and they possess piercing-sucking mouthparts that they use to suck body fluids from their prey. Damsel bugs attack any small insects they encounter, including aphids, *Lygus* bugs, weevil larvae, and small caterpillars.

There is also a variety of spiders in alfalfa that prey on insects. The most effective of these are the **crab spiders,** which search for prey in the foliar canopy without use of webs. Recent studies have indicated that these spiders may be quite important as natural enemies of insects in field crops. Additional information about beneficial insects can be found at www.agr.okstate.edu/alfalfa.

Parasites of Insects

The most common parasites of plant-feeding insects in alfalfa are tiny wasps that range in color from black to brown or orange. Several species parasitize aphids by inserting eggs into their hosts using an ovipositor shaped like a needle. The larval and pupal stages of the parasites grow inside the hosts, transforming the hosts into "mummies" before the adult wasps emerge. In a similar manner, two species of imported parasitic wasps attack larvae of the alfalfa weevil by inserting eggs into hosts (Plate 33). The parasitic larvae consume the internal organs of their hosts, and after the weevil larvae have spun their silken cocoons, the parasites spin cocoons within those of the weevils (Plate 34). Numerous species of parasitic wasps attack foliage-feeding caterpillars. There are also many parasitic flies that attack foliage-feeders, typically sticking eggs on the body surface. The larvae hatch and bore into the bodies of their hosts to consume the internal organs. Studies conducted in Oklahoma have shown that as many as 50-60 percent of foliage-feeding caterpillars may be killed by parasites.

Pollinators

The most effective pollinators of alfalfa in Oklahoma are **bumble bees** (Plate 35) and **leafcutter bees** (Plate 36). While both of these bees occur naturally, their population levels are typically not high enough to provide all of the pollinators needed for a highly productive seed crop. There is no process available for rearing bumble bees for use as pollinators. Although leafcutter bees are reared as pollinators in some areas of the western U.S., they are not used extensively in Oklahoma. The most common species used to supplement naturally occurring pollinators for alfalfa seed production in Oklahoma is the **honey bee** (Plate 37).

With exception of those who place honey bees in fields, most alfalfa seed producers in Oklahoma rely on native bee populations for pollination. Over the years, there have been adequate numbers of bees of various species to sustain profitable seed production. However, wild populations of honey bees, in particular, have been reduced greatly by diseases and tiny parasitic mites. The need to supplement native bee populations by moving colonies of bees into seed production fields is greater than in the past. Also, the need to restrict the use of pesticides in seed fields once plants start blooming is critical. Follow recommendations related to sampling fields for potential pest problems before the onset of bloom. If applications are required after alfalfa plants start blooming, take care to minimize mortality of pollinators (spray in late evening and remove bee colonies from fields). Additional information on pollinators can be found at www.agr.okstate.edu/alfalfa.

Diseases of Insects

Insects are infected by a variety of disease agents including bacteria, viruses, and fungi. The most common diseases observed in pest species of alfalfa in Oklahoma are caused by fungal pathogens. The fungal diseases are quite inconsistent in their occurrence because they require frequent rain showers and high humidity to become infective. These conditions often do not exist in Oklahoma, even during spring. One of these fungal diseases has infected larvae and pupae of the alfalfa weevil since 1983. This disease kills alfalfa weevil larvae within 2-3 days of infection, with the remains of dead insects being either tan in color (Plate 38), from which the fungus forms spores to infect additional weevils, or black (Plate 39). Host remains that are black contain resting spores that survive until the next season. When pupae are infected by the fungus, they invariably turn black and produce resting spores. Under optimal environmental conditions of frequent rainfall and moderate temperatures, this disease has been found to kill over 90 percent of weevil larvae and pupae. Unfortunately, these conditions do not occur often enough for the fungal disease to provide consistent control of the alfalfa weevil in Oklahoma.

There is also a fungal disease of pea aphids that may occur during periods when high population densities are present with frequent rainfall. Infected aphids die within 2-3 days, leaving remains that are brown to tan in color. As with the disease of the alfalfa weevil, this pathogen may kill a high percentage of aphid populations when optimal environmental conditions prevail.

Weed Pests in Alfalfa

Alfalfa is stressed by weed interference during establishment and in thinning stands. Alfalfa does not occupy all of the ground area at these two stages, so weeds are able to establish and compete with alfalfa for soil nutrients, water, light, and space. Yield reductions of alfalfa due to weed competition in new stands often exceed 1000 pounds per acre, and severe infestations can cause stand failure. Yield reduction in thinning stands results in loss of 1/2 to 1 pound of alfalfa for every pound of weeds produced.

A number of weed species can compete with alfalfa. The weed species present in any field depends on soil type, environmental conditions, the previous cropping history, and the weed management practices. Weeds that have been documented in Oklahoma alfalfa fields are as follows:

Mustards

Bushy wallflower, **flixweed** (Plate 40), **shepherdspurse** (Plate 41), **tansymustard**, and **pepperweeds** (green, veiny). Mustards are a problem in fall-planted alfalfa and in thinning stands. The mustards emerge in late summer and early fall as soil temperatures decrease and fall rains occur. Seedlings grow as rosettes in fall and early winter; then they initiate upright growth in late winter, flowering in April and May. Mustard flowers have four petals and four sepals. Peeperweeds have no petals, so they appear green when flowering; shepherdspurse (Plate 41) has four white petals, and the other listed mustards have four yellow petals. The mustards can be effectively controlled in fall-planted alfalfa with herbicides applied to actively growing rosettes in October and November. In thinning established stands, mustards can be controlled with residual herbicides applied in January and February when alfalfa is dormant.

Other Winter Broadleaf Weeds

Buckhorn plantain, **common chickweed**, **curly dock** (Plate 42), **cutleaf eveningprimrose** (Plate 43), **dandelion**, **henbit**, **musk thistle**, **plains coreopsis**, **prickly lettuce** (Plate 44), **red horned poppy**, and **spiny sowthistle**. Buckhorn plantain, curly dock, and dandelion are perennials. It is important to control seedlings of these perennials in fall planted alfalfa with herbicides applied in October and November. The rest of the listed weeds are annuals, and most of these weeds respond best to postemergence herbicides applied in the fall.

Pigweeds

Palmer amaranth (Plate 45), **redroot pigweed**, **tall waterhemp**, and **tumble pigweed**, in both new spring stands and thinning stands. The pigweeds start emerging in spring with warming soil temperatures and rainfall events in April and May, and new flushes of seedlings can occur throughout the summer whenever rainfall events (or irrigation) keep the soil surface moist for several days and the soil surface is not shaded by standing forage. Pigweeds are a big problem in thinning stands, since there can be emergence and establishment of these weeds after each cutting of alfalfa, if there is good soil moisture at cutting.

Other Summer Broadleaf Weeds

Buffalobur, **common ragweed**, **dodder** (Plate 46), **horseweed**, **kochia** (Plate 47), **lambsquarters** (common, slimleaf), and **Russian thistle**. These weeds usually have only one big flush of germination. Kochia, lambsquarters, and Russian thistle emerge in late winter, while buffalobur, common ragweed, and dodder emerge during the spring.

Annual Bromes

Cheat (Plate 48), **downy brome** (Plate 49), **Japanese brome**, and **rescuegrass**. The annual bromes emerge in late summer and early fall as soil temperatures decrease and fall rains occur. They tiller in fall and early winter, and then joint (initiate upright growth) in late winter, with flowering in May and June. Cheat and rescuegrass are fairly common in fall-planted alfalfa, while downy brome is a major weedy grass in thinning stands. In seedling alfalfa stands, best control of bromes is achieved with early fall applications of herbicides. In thinning established stands, bromes can be controlled with some of the residual herbicides applied in January and February when alfalfa is dormant.

Other Winter Grasses

Annual bluegrass, **little barley**, **jointed goatgrass**, **ryegrass**, and **volunteer wheat** (Plate 50). Annual bluegrass and little barley are minor problems in thinning stands of alfalfa. Jointed goatgrass, ryegrass, and volunteer wheat are all major competitors in fall-planted alfalfa; goatgrass and ryegrass are also a problem in thinning stands. In seedling stands, best control of all listed grasses is with fall applications of herbicides. Ryegrass can also be controlled with spring applications.

Summer Grasses

Barnyardgrass, **bermudagrass**, **crabgrasses** (smooth or large; Plate 51), **cupgrasses** (prairie or southwestern), **foxtails** (green or yellow; Plate 52), **goosegrass**, **johnsongrass**, **sandburs**, **sprangletops** (bearded or red), and **windmillgrass**. Most of these summer grasses can be a problem in new spring stands and thinning stands. The only exception is windmillgrass, a perennial which only infests thinning stands. Germination of the summer grasses is similar to pigweeds in that they start emerging in spring and new flushes of seedlings can occur throughout the summer when conditions for germination are favorable (high soil moisture). Bermudagrass and johnsongrass are perennials that can be selectively controlled by repeated herbicide treatments. Windmillgrass occurs primarily in thinning stands and is not controlled with selective postemergence herbicides. The other weeds listed are annuals. These annuals must be controlled while small and actively growing.

Weed Management in Seedling Stands

Competitive weeds should be controlled in new alfalfa plantings to help ensure establishment of a full stand of alfalfa. It takes more than 11 seedling alfalfa plants per square foot to give maximum alfalfa production at first harvest after fall planting. In Oklahoma, a planting rate of 12 pounds of alfalfa seed per acre into a good seedbed should give 14-19 seedling plants per square foot by November and 35-45 alfalfa stems per square foot by the following July. A full stand of alfalfa in Oklahoma is defined as a stand with at least 30 stems of alfalfa per square foot over the entire field.

Winter weeds such as henbit and chickweeds in fall-planted alfalfa have seedling vigor that is similar to alfalfa, so a few of these weeds per square foot can be tolerated. However, the seedlings of most weeds are more vigorous than alfalfa. For example, just one plant per square foot of taller-growing weeds like mustards can result in a 10 percent yield reduction of alfalfa and six per square foot can result in 60 percent yield loss of alfalfa. A summary of competitiveness of several weeds in fall-sown alfalfa is listed in Table 2-4.

The exact competitiveness of weeds is difficult to predict, since it depends on date of emergence of weeds and alfalfa, weather conditions (rainfall, temperature), and soil fertility level. With extended wet and warm weather conditions, when weeds outgrow and shade the alfalfa, several competitive weeds per square foot can result in the death of many alfalfa plants, thus stand failure.

The first step toward obtaining a weed-free alfalfa stand is to plant weed-free alfalfa seed into a weed-free seedbed. A good alfalfa site should be fairly weed-free (including fencerows). Weeds should be controlled in rotational crops preceding alfalfa planting to minimize weed seeds and plants of perennial weeds. This is especially important in western Oklahoma where weather conditions can be too dry for proper seedbed preparation during summer before planting. In these areas it is critical that deep tillage operations and perennial weeds be controlled in rotational crops at least two years before planting alfalfa. Perennial weeds such as curly dock and bermudagrass are difficult to control in established alfalfa.

Table 2-4. Summary of competitiveness of weeds in fall-sown alfalfa

Weed Group (Example)	Weed Density	Yield Loss
	weeds/ft^2	%
Least Competitive	10-20	none
(Henbit)	> 20	slight
Somewhat Competitive	1-4	5-10
(Shepherdspurse)	> 4	10-50
Most Competitive	1-2	10-30
(Tansy Mustard)	3-6	30-90
	> 6	50-100
(Cheat and Wheat)	1-2	5-20
	3-6	10-60
	> 6	20-100

Another reason to control weeds in seedling alfalfa is to get producers focused on total pest management in new stands. Often producers do not scout and properly control insect problems in new stands of alfalfa. Combined stresses from weeds and insects result in seedling alfalfa plants that are often severely stunted or killed. This results in significant reductions in alfalfa production at first harvest and is one of the causes of poor stands.

Fall-Planted Alfalfa

Traditionally, most of the alfalfa in Oklahoma has been planted in the fall, and weeds have not been a major problem. However, with the shift toward minimum tillage in wheat (grown in rotation with alfalfa) plus planting wheat early for grazing, winter weeds are now a common problem in fall plantings of alfalfa. Postemergence herbicides are a better option for controlling weeds in fall-planted alfalfa than preplant herbicides. Since there are good postemergence herbicides available for control of various cool-season weeds, it is possible to determine weed problems in October and then treat only when problems exist. Thus, it is important to scout new plantings of alfalfa for emerged weeds once a week after planting and then apply the appropriate herbicide(s) in the fall to ensure the establishment of a full stand of alfalfa.

In most cases, it is profitable to control all competitive weeds in fall-planted alfalfa. Alfalfa planted in early September and kept pest-free will produce 4-5 tons per acre of weed-free hay in the first season. In addition, establishing a full stand of healthy alfalfa can extend the productive life of the stand by 2-3 years. Putting a dollar amount on profitability for the duration of the stand is not easy. It depends on weed infestation at establishment (weed species present, competitiveness of weeds, number of weeds), weather conditions during stand life, management practices of producers, and how hay is marketed.

However, short-term partial budgets can be used to estimate and provide some guidance on controlling weeds. Top prices are paid for weed-free, high-quality alfalfa sold to dairies and horse owners. First harvest forage yields from fall-planted alfalfa average 1.75 tons of hay per acre. Value of first harvest hay would be $140 (1.75 tons at $80 per ton for weed-free hay). Alfalfa hay with a few weeds (5-15 percent weeds) is normally discounted $19 per ton when top quality hay is in short supply. This represents a loss of $33.24 (1.75 tons at $19) at first harvest. Cost to control weedy grasses or broadleaf weeds is approximately $15 per acre, and cost to control both weedy grasses and broadleaf weeds is approximately $29 per acre. Thus, the premium paid for first-harvest hay ($33.24) would cover the cost of controlling various types of weed problems in fall-planted alfalfa. Added benefits of controlling weeds in fall-planted alfalfa include 15 percent increase in alfalfa yield at second cutting, assurance of a productive stand, giving high quality hay for a number of years, and an extended stand life.

If hay is not going to be marketed as top-quality alfalfa hay, but is likely to go to beef cattle, then some weeds in newly established alfalfa can be tolerated. Seedling alfalfa must be scouted about one month after emergence to determine the weed infestation. Some examples of infestations and recommendations are as follows:

A. If one competitive broadleaf weed or grass plant per square foot is found, spray in October or November. These weeds will significantly reduce alfalfa yields and could result in shortened stand life.
B. If less than one competitive broadleaf weed or weedy grass plant per square foot is found, then control is not critical. However, if there are areas where weeds are thicker, or if weeds are outgrowing and shading alfalfa, institute control measures to ensure that a healthy, full stand is established.
C. If broadleaf weeds consist of henbit or chickweeds, there is no need to spray. These weeds are not competitive. Also, postemergence herbicides are not effective on them.
D. If winter weeds are not controlled, it is important to schedule first-cutting early to maximize hay quality and minimize the damage to alfalfa from shading. Ideally, such stands should be cut in April when weedy grasses are in the boot stage.
E. If weeds are only a problem in borders of fields, consider spraying only those areas.

Scouting during fall and winter for weeds and insects is critical in newly planted fields. Competitive weeds should be controlled with a herbicide when population densities of these weeds approaches one weed per square foot. Infestations of blue and spotted aphids should be monitored closely and controlled with insecticides before they reach the economic threshold since insect damage results in seedlings that are not competitive with weeds.

Grazing of fall-planted alfalfa before it flowers the following spring is not recommended since it retards root-growth and may decrease stand density. However, grazing can be used as a salvage treatment if aggressive weeds are not controlled in the fall. Once weeds start shading alfalfa, it will stop growing. Grazing maybe less damaging than shading by weeds. Grazing or cutting the first harvest early, before the winter weeds mature, is another way to minimize the damage by weeds during establishment. This is particularly true with cheat, volunteer wheat, and mustards. Many weeds are palatable and have acceptable protein levels if grazed or harvested before they mature.

Spring-Planted Alfalfa

Seedlings of most summer weeds (crabgrasses, foxtails and pigweeds) are more vigorous than alfalfa and must be controlled in all spring-planted alfalfa. Weeds are always a problem in spring-planted alfalfa, so using a preplant herbicide is good insurance. Postemergence herbicides are available, but they are more expensive and not as effective as preplant herbicides. Failure to control weeds in spring-planted alfalfa will often result in stand failure.

Spring establishment of alfalfa should be avoided. Pest stresses from weeds, insects, and diseases are much greater in the spring, plus environmental conditions for alfalfa establishment are not as favorable in the spring. As a result, most stands established in the spring are not as productive as those established in the fall. In addition, stand life of spring-established fields is usually shorter.

Weed Management in Established Stands

Full Stands

Weeds are not competitive in properly managed full stands of established alfalfa. Properly managed stands have a soil pH of about seven, with proper soil fertility and effective pest management. Weeds germinate in full productive stands, but are not able to grow due to competition and shading by the alfalfa. Also, frequent mowing for hay coupled with the relatively short regrowth time of alfalfa makes established alfalfa competitive even with established weeds. For example, mowing at 1/10 bloom stage, under high moisture conditions, along with an adequate fertility program has been noted to suppress perennial weeds like johnsongrass. Thus, in established alfalfa fields, the presence of weeds is a sign of poor management or a thin, diseased stand.

The full stand life of a multiple-pest resistant variety that is managed properly varies from 4 to 8 years, depending on location in the state. In general, stand life increases from east to west across the state. The shorter stand life in eastern Oklahoma is attributed to greater incidence of diseases associated with more rainfall.

Thin Stands

When alfalfa stem density declines below 30 stems per square foot, alfalfa does not occupy all of the area, and production is decreased. When this happens, weeds are able to grow in areas not occupied by alfalfa and compete with it; thus, an additional loss of alfalfa yield results. For each pound of weeds produced in these thin stands, there is a loss of 1/2-1 pound of alfalfa. The first weed problems to occur in thinning stands are often winter annual weeds. These weeds include henbit, mustards, and downy brome.

A practical way to determine that a stand is no longer a full stand is when weedy grasses and broadleaf weeds make up more than 5 percent of the forage at harvest time. When this happens, the most economical decision is to start controlling winter weeds with a herbicide. First-harvest forage yields from stands with 20-30 alfalfa stems per square foot average about 1.5 tons of hay. Value of this hay, weed-free, is $120 per acre (1.5 tons at $80/ton). Weedy alfalfa hay with 15 percent weeds is, on average, discounted by 20 percent; thus the value of 1.5 tons with 15 percent weeds is only $96 (1.5 tons at $64/ton). The loss due to weedy hay in this case is $24 per acre ($120-$96). A dormant application of a herbicide costs about $18/acre. thus, the cost of controlling winter weeds is more than covered by the $24 saved by cutting weed-free hay.

Added benefits of controlling winter weeds in thinning stands include a 15 percent increase in alfalfa yield at second harvest and several years of extended stand life, provided good management practices are continued during this period. It is very important to keep insect damage in alfalfa to a minimum, since it has been proven that weed growth increases in insect-stressed alfalfa. Also, it is important to keep soil nutrient levels adequate in thinning stands to keep alfalfa productive.

Pigweeds are the major broadleaf weed problem in thinning alfalfa stands. Pigweeds can usually be controlled, but scouting and timing of herbicide treatments are critical. Crabgrasses and foxtails are the most common summer grasses in thinning stands. On sandy sites, sandburs also can be a major problem. Windmillgrass often becomes the dominant summer grass in stands with less than 20 alfalfa stems per square foot. Control of weedy grasses with herbicides is more difficult than control of pigweeds, but it is possible. A better solution often is to consider using the hay as mixed grass-alfalfa hay for beef cattle. These grasses can actually supplement total forage production since they grow in areas not occupied by alfalfa.

Control of summer weeds is difficult to achieve with most dormant season herbicides, since most herbicides do not have enough soil residual activity to control weeds all season. However, some herbicides can be applied in January-February and still have enough residual to control some summer weeds, provided enough herbicide gets incorporated into the soil. Pigweeds are best controlled with Pursuit applied to seedling weeds after the first or second harvest. It will control the emerged pigweeds and provide summer-long control of later-emerging pigweeds. Butyrac 200 can effectively control actively growing small pigweeds, but must be reapplied after each harvest as new pigweeds emerge.

Some effective options for summer grass control include using Zorial before grasses germinate in the spring and using either Poast Plus or Select as postemergence sprays. Zorial can control crabgrass all summer, but control of some of the other annual grasses is marginal. Poast Plus and Select have no soil residual activity, so new grasses emerging after each harvest must be sprayed before the alfalfa canopy closes.

Economics of controlling summer weeds in thinning stands is not very predictable or favorable with nonirrigated alfalfa. Summer weeds usually are not a problem in first, second, and third harvests, but occur in later harvests during wet summers. Because production of forage at fourth, fifth, and sixth harvests is usually less than a ton per acre at each harvest, control may not be profitable. Summer weed problems are quite variable in thinning stands, being influenced by species, number, and dormancy of weed-seed reserves in the soil, rainfall events throughout the summer, and timing of hay harvest. Generally there are enough weed seeds germinating at each cutting in the spring to cause a significant weed problem during a wet summer. This means that weed control might be needed after each harvest, or that a long-life residual herbicide could be needed to control weeds for 2-3 months. Finally, herbicide treatment costs for control of summer weeds can be expensive, since multiple treatments and herbicide mixtures are often required to adequately control summer weeds. Herbicides applied for control of summer weeds usually are not profitable since summer hay yields are often too small to cover the herbicide cost.

Weed Control by Grazing

Harvest of alfalfa by grazing should be integrated into every producer's management of established alfalfa. Flash-grazing of alfalfa in December or early January each year when the soil is dry or frozen is an effective way to utilize fall alfalfa production, decrease pest problems, and increase the profitability of an alfalfa stand. As stands thin below 30 stems per square foot and summer weeds start making up more than 10 percent of forage in July and August, grazing is probably the most profitable harvest alternative. Excellent stocker gains are possible even in weed-infested fields, and bloat problems are manageable in the summer when mature alfalfa is mixed with summer grasses. Harvest of spring growth by grazing in March through April can be an effective way to reduce spring insect problems. However, this practice is not usually recommended since bloat problems on essentially pure stands of alfalfa are very difficult to manage during this period and May weed problems are increased by early spring grazing.

As stands thin to fewer than 20 alfalfa stems per square foot, fall drilling of wheat or ryegrass into the alfalfa and then harvesting the forage by grazing may be the most profitable option. These improved forage grasses are competitive with weeds and essentially replace them in the areas not occupied by alfalfa. As a result, the spring forage on these areas is significantly increased, and the mixture of grass and alfalfa is excellent forage for stockers. Grazing of these alfalfa-grass sites in early spring also effectively decreases alfalfa weevil and aphid populations below economic threshold levels, thus reducing the cost of pest control.

Wheat would be a better choice than ryegrass for obtaining a June alfalfa hay harvest. Wheat does not decrease May alfalfa production and has limited regrowth after May harvest. As a result, a June cutting of essentially all alfalfa would be possible with wheat overdrilled. Ryegrass is more competitive with alfalfa, so significant ryegrass would be present in June. Having ryegrass overdrilled probably would be the best option if the area was only going to be grazed.

Alfalfa Diseases

Alfalfa in Oklahoma is subject to many different disease organisms. Even in the driest areas of the state, diseases attack alfalfa and reduce yield, stand longevity, and sometimes forage quality. A few diseases are restricted to areas with high rainfall. The most important alfalfa diseases statewide in Oklahoma include:

***Phytophthora* root rot.** The most common disease in Oklahoma is associated with wet, warm soils. It is important as a seedling disease and throughout the life of an alfalfa stand. (See page 25, "Root and Crown Diseases" in this chapter.)

Bacterial wilt. The most widespread disease of alfalfa in the nation. (See page 27, "Root and Crown Diseases" in this chapter.)

***Fusarium* rot.** A disease associated with warm production environments. (See page 26, "Root and Crown Diseases" in this chapter.)

Anthracnose. A stem disease present throughout Oklahoma. It requires mild temperatures and high humidity. (See page 24, "Leaf and Stem Diseases" in this chapter.)

***Verticillium* wilt.** The most recently discovered, important crown-rotting alfalfa disease. It is not the same fungus that attacks cotton, peanuts, etc. (See page 27, "Root and Crown Diseases" in this chapter.)

Aphanomyces. Like phytophthora root rot, it is a wet soil disease. (See page 26, "Root and Crown Diseases" in this chapter.)

Leaf and stem spots. Caused by several different fungi. (See page 24, "Leaf and Stem Diseases" in this chapter.)

Nematodes. Symptoms of stem nematodes are frequently noted in 2- to 4-year-old stands. Other species are present, but their severity in Oklahoma is unknown. (See page 27, "Nematodes" in this chapter.)

Viruses. Several viruses cause variable symptoms in Oklahoma alfalfa and reduce plant vigor. (See page 27. "Viruses" in this chapter.)

Damping off. A complex of fungi that debilitate and kill seedlings growing in cool, damp conditions. (See page 26, "Root and Crown Diseases" in this chapter.)

Sclerotinia. A fungal disease rarely seen in Oklahoma, but one that can devastate fall plantings. (See page 27, "Root and Crown Diseases" in this chapter.)

Texas root rot. Also called cotton root rot, it is found in extreme southern Oklahoma in fields with a history of cotton production. This fungus can remain alive in the soil for decades. (See page 26, "Root and Crown Diseases" in this chapter.)

Diseases can be a limiting factor in alfalfa production. In both hay and seed production, diseases can cause serious losses in yield, quality, and stand persistence. Death of plants is sometimes quick and obvious, but more often plant-kill by diseases is not so obvious. Diseases can kill 5-10 percent of the plants in a stand each year. In many cases, alfalfa plants live for several years after becoming infected by diseases. This reduces the vigor and competitiveness of infected plants; thus, weeds are better able to compete. The combined stress of diseases, weeds, and insects decreases productivity and eventually results in the death of infected plants. Mortality of plants results from diseases caused by fungi, bacteria, nematodes, and viruses.

The most effective means of controlling the first six diseases listed above is the use of multiple-pest resistant varieties. All varieties released in the last decade possess adequate resistance to these diseases for most conditions in Oklahoma. It is important to note that much of the alfalfa known as Oklahoma common or VNS (variety not stated) lacks resistance to any of these important diseases.

Maintaining good drainage, harvesting in a timely fashion, and using adapted, multiple-pest resistant varieties combine to provide an excellent management approach to control these diseases. While research continues on the last six dieases listed above, varieties with effective resistance are lacking, and proper cultural practices (including crop rotation, site selection, and seed bed refinement) are the only control options available. More progress has been made in the development of disease resistance in alfalfa than from directly breeding for increased forage yield or persistence.

Identifying pathogens that cause symptoms on plants can be difficult. Producers are encouraged to consult their County Extension Office or the Plant Disease and Insect Diagnostic Laboratory at OSU (see www.ento.okstate.edu/) for assistance in determining causal agents. The following discussion gives a brief description of diseases that have been most frequently found on alfalfa in Oklahoma in recent years. Additional information on diseases, including photographs, can be obtained through the Oklahoma Alfalfa Calendar at www.agr.okstate.edu/alfalfa.

Leaf and Stem Diseases

Leaf and stem diseases that commonly infect alfalfa cause losses by reducing plant vigor, yield, and hay quality (primarily by causing leaves to drop). The effects of these diseases can range from slight to severe, even to the point of killing enough plants so that an alfalfa stand is no longer profitable. Losses from individual leaf spot diseases are difficult to measure since they are seldom found separately.

Anthracnose. (See Plate 53.) A stem disease that normally infects alfalfa during the warmest periods of the year. Only planting resistant varieties effectively controls it. Symptoms vary from a few irregularly shaped blackened areas to large sunken, oval to diamond- shaped lesions on the stems. These lesions are bleached with grayish-white centers. Black fruiting bodies of the fungus develop in the lesions. The lesions may enlarge, coalesce, girdle, and kill one to several stems on a plant. A conspicuous symptom is straw-colored to pearly white stems scattered through the field in summer and fall. Dead shoots may droop to form a "shepherd's crook" appearance as a result of rapid wilting of the stem. Although it is typical of anthracnose, this symptom may also be caused by other conditions. The anthracnose fungus causes a crown rot, producing black or bluish-black discoloration of invaded tissues. This symptom is often observed when stems are broken off at the crown. The fungus survives in infected stems and crowns in fields and in harvested hay.

Downy Mildew. (See Plate 54.) Appears as light grayish-green areas on the leaves, giving the field a light green appearance. Other fungus leaf diseases of alfalfa generally start on lower leaves and progress up the plant, but downy mildew symptoms appear first on younger leaves near the top of the plant. Infected leaves may be somewhat curled and distorted. Under severe infection, entire stems may be thickened and shortened. In high humidity, the lower surface of infected leaves shows patches of gray to slightly purplish downy growth, which represent the spore-producing structures of the fungus. Spores are disseminated by wind and splashing rain.

Optimum conditions for downy mildew infections exist with near 100 percent relative humidity and temperatures between 50° and 65°F. In Oklahoma, this disease is most serious in the spring during the growth of the first crop. Newly seeded alfalfa is most severely affected. Susceptible seedlings may be killed or weakened so that they cannot survive environmental stresses, such as a drought period. When downy mildew becomes severe, the alfalfa should be cut to stop disease development.

Lepto leaf spot. (See Plate 55.) Also called pepperspot. Can be found in alfalfa fields at almost any time in the growing season, but it is more prevalent during cool, wet weather. This is the first leaf spot to develop on regrowth after cutting.

The leaf spots are variable from small (pinpoint) to large (1/8 inch) diameter spots with light tan centers and dark margins surrounded by a yellow halo. When conditions favoring infection and disease development coincide with rapid regrowth, lesions appear as large light tan to almost white areas that coalesce and kill entire leaves. Early cutting of hay is of little value in preventing this disease, since it builds up soon after harvest and older leaves become more resistant.

Spring black stem. (See Plate 56.) Can infect all above-ground parts of alfalfa, appearing as small black spots on lower leaves, petioles, and stems. The infection may extend to the crown and upper roots. Blackened spots on stems are irregularly shaped. In a cool, wet spring, entire shoots are blackened, and stems become brittle and break. Cutting in the late bud to early bloom stage reduces losses from spring black stem because the disease builds up most rapidly after the growth is tall enough to shade lower leaves.

Summer black stem. (See Plate 57.) Recognized by loss of leaves and blackened stems. Also shows up as gray-brown leaf spots with irregular margins. The spots may be as large as 1/4 inch in diameter. Tissue around these spots soon turns yellow. One spot on a leaflet causes it to yellow and drop within a few days.

Summer black stem generally appears after the first cutting of hay. The fungus develops most rapidly at temperatures of 80° to 90°F and near 100 percent humidity. Cutting the hay crop at bud stage is consistent with making high-quality hay and reduces losses from summer black stem.

Root and Crown Diseases

Root and crown rots are usually caused by a number of common soil-borne fungi. These fungi weaken infected plants and reduce forage yield and stand longevity.

***Phytophthora* root rot.** (See Plate 58.) Causes damping-off of alfalfa seedlings and root rot in older plants. Seedlings are often killed within a few weeks after emergence or in spring after fall planting. Entire stands are sometimes killed. Young plants rapidly turn yellow or red, then wilt, and die. Infected taproots have brown to black lesions, and when severe, the lower end of the taproot is black and rotted off 1-6 inches below the soil surface. *Phytophthora* root rot occurs in wet, poorly drained soils during extended periods of rainfall or excessive irrigation. It can be detected by digging surviving plants in areas where stands have been thinned. If the soil dries out during disease development, some plants may recover by growing new lateral roots above the rotted area, but the resulting shallow root system limits drought tolerance and reduces yield.

This is the most important alfalfa disease in Oklahoma. Essentially all soils have the fungus that causes this disease. The fungus can be dormant in the soil for many years and become active when the soil remains saturated for several days and the soil temperature is above 60°F. When the soil temperature is below 60°F, alfalfa can tolerate extended periods of flooding. All varieties for Oklahoma released in the last 20 years have adequate levels of resistance to this disease. Other than resistant varieties, the only form of control is assuring good internal and surface drainage before stand establishment.

In poorly drained sites, *Phytophthora* root rot and other diseases can kill most alfalfa plants after 1-2 years. Weedy grasses frequently invade these wet areas, as there are not enough alfalfa plants to dominate the area. Sowing white clover (Ladino) in these low areas can reduce the weed infestation; however, white clover dries more slowly in the windrow than alfalfa.

***Aphanomyces* root rot.** (See Plate 59.) An important disease of wet soils. It stunts and kills seedlings rapidly and causes chronic root disease in established plants. Infected seedlings develop yellow cotyledons followed by chlorosis of other leaflets. Roots and stems initially appear gray and water-soaked, and then turn light to dark brown. Seedlings become stunted but remain upright. *Aphanomyces* reduces root mass on established plants. Nodules are frequently absent or decayed. Infected plants exhibit symptoms similar to nitrogen deficiency and are slow to regrow following winter dormancy or harvest. For best results, select varieties with high levels of resistance to both *Aphanomyces* and *Phytophthora* root rot.

Damping off. A germination and seedling disease. It is associated with less-than-ideal germination conditions, including prolonged wet and cool periods. During germination, seeds may be infected and contents reduced to a brown gelatinous mass in the seed coat, or the radicle and cotyledons may become brown and soft after emergence. *Pythium* spp. and *Rhizoctonia solani* are normally the causal agents for damping off. Phytophthora and Aphanomyces may cause somewhat similar symptoms. Seed protectant fungicides are usually effective in reducing the degree of damping off. Planting in conditions that are conducive to rapid growth of seedlings will reduce seedling loss. Damping off is most likely to be a problem with spring planting or planting after early October.

***Fusarium* root and crown rots.** (See Plate 60.) Caused by several species of the *Fusarium* fungus. External symptoms are first evident when the leaves curl at the edges, then wilt. When the taproot is cut lengthwise, it is discolored light brown to black. Damage varies from irregular brown rotted areas to complete disintegration of the root and crown. Such rots usually occur after injury from freezing, harvesting, or insect feeding. The disease generally progresses slowly and becomes most noticeable following periods of stress caused by insufficient moisture, severe heat, or mismanagement. All adapted multiple-pest resistant varieties have good levels of resistance, which is the only known control for this disease.

Texas root rot. (See Plate 61.) Also known as *Phymatotrichum* root rot and cotton root rot. In Oklahoma, this disease occurs only along the southern border. The *Phymatotrichum* fungus does not survive cold winter temperatures. This root rot causes rapid death of plants, often after excellent growth. The disease kills plants in somewhat circular areas within fields ranging from a few square yards to an acre or more in size. Death occurs within a few days of the first wilting of the plants. The whole root system of affected plants decays, and the plants can be pulled from the soil with little effort. Affected plant roots show a growth of fine brownish strands of the fungus. These strands are called rhizomorphs and are a distinguishing characteristic of the disease. Cereal crops and sorghum are resistant to *Phymatotrichum* root rot, but because this organism persists for long periods, traditional 3-6 year crop rotation of alfalfa and cereals is ineffective as a control measure. There are no known resistant varieties to Texas root rot.

Bacterial wilt. Symptoms begin to appear in the second and third year and may cause serious stand losses in 3- to 5-year-old stands. Affected plants turn yellow, become stunted, and in early stages of disease, are scattered throughout the stand. Severely infected plants are stunted with many spindly stems and small, deformed leaves. Diseased plants are most evident in regrowth after clipping. Cross sections of the taproot show a ring of yellowish brown discoloration near the outer edge. All adapted multiple-pest resistant varieties are resistant to this disease.

***Verticillium* wilt.** Can reduce yields up to 50 percent beginning the second harvest year and can severely shorten stand life. Early symptoms include v-shaped yellowing on leaflet tips, sometimes with leaflets rolling along their length. The disease progresses until all leaves are dead. Initially, not all stems of a plant are affected. The disease slowly invades the crown, and the plant dies over a period of months. Root vascular tissues may or may not show internal browning. Many alfalfa varieties are resistant to this disease.

The following measures minimize the chances of introducing this fungus and spreading the disease between and within fields:

- Plant disease resistant varieties.
- Practice crop rotation. Deep plow *Verticillium*-infested fields and do not plant alfalfa for at least three years. Corn and small grains are important non-hosts. These crops should fit well into a rotation with alfalfa.
- Harvest non-infested fields first. Then harvest infested fields at late bud or early flower stage. Early harvest can limit some yield and quality losses caused by *Verticillium* wilt and can slow the spread of the fungus throughout fields.

***Sclerotinia* crown and stem rot.** Caused by the same fungus that causes *Sclerotinia* blight in peanuts. Consequently, alfalfa should not follow peanuts when *Sclerotinia* blight has been a problem. The *Sclerotinia* fungus can kill alfalfa seedlings rapidly. Symptoms first appear in the fall as small brown spots on the leaves and stems. Then the plant tops wilt and die. In early spring, crowns of infected plants become soft with a brown white fluffy mass of fungal mycelium. Hard, black fruiting bodies (sclerotia) form in this fungus mass and may adhere to the surface or be embedded in the stem or crown area. These hard, black fruiting bodies are the survival stage of the fungus. *Sclerotinia* can survive in the soil for up to 4 years.

This disease is not known to occur in Oklahoma alfalfa. In areas of the nation where this fungus is severe, fall-planted stands are frequently devastated; consequently, late summer and fall stand establishment is avoided. The disease is rarely important in spring-planted stands.

Viruses

A number of viral diseases of alfalfa have been described, but relatively little is known about their distribution and importance in alfalfa, with the exceptions of **alfalfa mosaic virus**, **alfalfa enation virus**, and **lucerne transient streak virus**. Often, viruses are carried by aphids, leafhoppers, and other plant-sucking insects. There is no effective control of viruses, but minimizing the various plant-sucking insects by scouting, timely treatment, and using resistant varieties may offer a degree of control.

Nematodes

Plant-parasitic nematodes are microscopic roundworms that cannot be seen with the unaided eye. **Stem nematodes**, **root lesion nematodes**, and **root-knot nematodes** are the most damaging plant parasitic nematodes found in Oklahoma alfalfa fields. Their importance is a result of their pathogenic effects on alfalfa and their ability to become involved with other pathogens in disease complexes, thereby increasing disease severity.The only way to know for certain if nematodes are present is to collect soil and roots—or in the case of stem nematodes, above-ground plant parts—and send a sample to a laboratory equipped for extracting and identifying nematodes. For details on sampling for nematode analysis, consult the County Extension Office or the Plant Disease and Insect Diagnostic Laboratory at OSU www.ento.okstate.edu.

Alfalfa stem nematode. One of the few nematodes that feed on plant foliage, it can cause severe stunting of alfalfa. Infected plants have a bushy appearance and usually possess thickened stems and shortened internodes (Plate 62). Leaves of infected plants often appear crinkled. High populations of stem nematodes cause stunting and can kill alfalfa plants. A stand of alfalfa may decline quite rapidly after stem nematodes become established, sometimes reducing alfalfa production enough to be unprofitable one year after infection is detected.

Symptoms of alfalfa stem nematodes are normally noticed in the second or third production year. The first symptoms may be limited to small areas during late March or early April. The symptoms may disappear as temperatures rise, but they will return in following years over larger areas until most of the alfalfa plants in the field have symptoms of damage. Stand thinning accelerates when the stem nematode is present.

Resistant varieties are available but do not seem to be effective in Oklahoma. The best control for stem nematodes is to prevent their spread by cleaning any remaining alfalfa hay, plant parts, and soil from haying equipment before moving from an infested area. The nematodes are carried in plant debris on equipment from one field to another. Rotation to crops such as small grains, sorghum, or corn for 2-3 years will reduce alfalfa stem nematode and root-knot nematode populations; however, crop rotation is an ineffective control of root lesion nematodes because of their wide host range.

Root lesion nematodes. Widespread in their distribution, occurring frequently throughout temperate regions, they attack a wide range of crop and weed plants. High infestations of root lesion nematodes can reduce forage yields, decrease cold tolerance, and increase infections by soil-inhabiting fungi. Damage caused to alfalfa plants is enhanced by root lesion nematodes predisposing roots to soil microorganisms.

Aboveground symptoms of root lesion nematodes are difficult to assess since other pathogens may produce similar symptoms. No visual symptom develops when nematode numbers are low, but when numbers are high, even when plant-growing conditions are ideal, infected plants become stunted. Feeding by root lesion nematodes generally causes dark lesions, overall browning of roots, and reduced growth.

Root-knot nematodes. Probably the most widely disseminated plant parasitic nematodes in the world, they rank high in economic importance as plant pathogens. Root-knot nematodes may build up large populations on alfalfa and are a major alfalfa production problem in many states. In Oklahoma, however, they appear to be less frequently encountered on alfalfa and are probably less important than stem and root lesion nematodes. Like the root lesion nematode, root-knot nematodes may be involved in disease complexes with other alfalfa pathogens.

Alfalfa plants infected by root-knot nematodes may become stunted, and the stand may be reduced. Infected roots branch excessively and have small galls. Root-knot galls are swelling of the tissue of the root itself, frequently involving the total diameter of the root, and should not be confused with Rhizobium bacterial nodules, which usually appear to be appendages attached to the root.

Mammalian Pests

Mammalian pests that occasional reduce alfalfa production or persistence and interfere with normal operations include rabbits, moles, gophers, voles, mice, rats, and deer. Cultural practices, combined with baiting, are the only practical control options.

Chapter 3
Alfalfa Stand Establishment

The keys to alfalfa stand establishment are summarized in the following statements. For additional information, see OSU Extension Circular E-949 (*Alfalfa Stand Establishment Questions and Answers*), www.agr.okstate.edu/alfalfa/pub/stand-949/stand-est.htm, or *The Oklahoma Alfalfa Production Calendar* at www.agr.okstate.edu/alfalfa.

The objective of alfalfa stand establishment is to obtain about 30 vigorously growing seedlings per square foot before extreme weather conditions prevail (hard freezes in fall and high temperatures in spring). Good planning, along with some "art" and good farming practices, are critical to reliable stand establishment. Although the exact steps required for successful stand establishment vary from farm to farm and from year to year, there are several keys to alfalfa stand establishment that can be helpful. In several discussions of these keys, important cost factors are highlighted. A discussion of crop rotation with alfalfa, some special circumstances related to alfalfa stand establishment, and a general stand establishment budget are topics that overlap several of the keys.

Alfalfa stand establishment checklist includes:

- **Site Selection and Soil Test.** Choose a deep, fertile, well-drained soil, free of damaging herbicides. Apply fertilizer and lime according to a reliable soil analysis.
- **Land Preparation and Seedbed Refinement.** Plow, level, and drain low areas well before planting. Develop a level, mellow, firm seed bed with small clods.
- **Variety Choice and Seed Quality.** Select adapted, pest-resistant varieties. Use weed-free, clean seed with good germination.
- **Seed Inoculation.** Use Rhizobium bacteria, specific for alfalfa.
- **Planting Date and Rate.** Plant during the periods running from August 15 to September 15 or March 15 to April 15. Plant 10 to 15 pounds per acre of good seed.
- **Seed Placement and Equipment Options.** Cover seeds with 1/2 inch of soil and press. Calibrate and adjust planters to place seed in a good environment.
- **Pest Control.** Control weeds, insects, and diseases.

Site Selection and Soil Test

Select **deep, fertile, well-drained loamy or sandy loam soils** for best stand productivity and longevity. Productive alfalfa stands require soils with adequate infiltration, yet sufficient clay and organic matter to hold moisture. Soil with good water-holding capacity is important because high alfalfa yields require large quantities of water (approximately six inches of available water for each ton of hay). It is also important to **avoid** sites that had herbicides used on previous crops that could result in phytotoxic effects (see "Herbicide Residue Problems with Rotational Crops" in this chapter).

Alfalfa roots can penetrate 25 feet in deep soils, and high yield and long stand life are attainable in sub-irrigated fields — those with a water table between 5 and 20 feet deep. If, however, the water table rises to the surface during warm seasons, alfalfa grows poorly and may even die from scald within a few days. Scald often kills alfalfa plants when water stands during bright sunny days. Oxygen is unavailable to roots, and the water holds in heat. Scald usually occurs in thin stands or just after harvest when foliage does not shade the soil. This differs from root rots in that no pathogen is involved and no genetic resistance is available.

Waterlogged soils have poor aeration, inhibit nitrogen fixation, and encourage certain root rot diseases. Several adapted varieties are available with root rot resistance. They perform better in wet soils than susceptible varieties but cannot tolerate extended periods of standing water.

Much of the alfalfa in Oklahoma grows along creek and river bottoms that do not flood for prolonged periods of time. These alluvial soils are usually deep with good drainage, and fertility problems (if they exist) can be corrected profitably. Alfalfa will grow in shallow soils, but growth is usually reduced by rapid depletion of water in shallow root zones; thus, overall production will be less, and stand longevity will be shorter.

Avoid using sites that may have herbicide carryover problems. Alfalfa is very sensitive to picloram (sold as Tordon 22K) and the sulfonyl-urea herbicides such as Ally, Glean, and Amber. Alfalfa is usually not listed as a rotational crop for these herbicides. When it is listed, there is a 22- to 34-month minimum rotational interval before alfalfa can be planted. Also, after application of several of these herbicides, alfalfa field bioassay must be performed before alfalfa can be safely planted. The bottom line is **herbicides used on previous crops can interfere with alfalfa establishment**. So it is important to read and follow rotational restrictions and other information on herbicide labels before using them. Most pesticide labels, as well as Material Safety Data Sheets (MSDS), can be found at www.cdms.net/pfa/LUpdateMsg.asp on the World Wide Web.

Test soil and correct nutrient deficiencies and pH (acidity) before planting alfalfa. Nutrient deficiencies should be adjusted at least one or two months before planting alfalfa and pH (acidity) should be adjusted one year ahead. Alfalfa uses phosphorus, calcium, and potassium heavily. In some soils, these quantities are readily available; whereas in others, many nutrients must be applied.

The cost of lime and fertilizer may seem high, but cutting corners on these important factors puts the other activities in jeopardy. An inexpensive soil test ($10 per sample) can save producers money by indicating which nutrients are deficient and by telling them what quantity should be supplied. This may help avoid the cost of unnecessary fertilizer. If soil analyses indicate the need for fertilizer and lime exceeds the high estimate, consider another site for alfalfa. Building up the fertility and pH over several years may be recommended. (See Chapter 4, "Fertilizing Alfalfa" for details.)

Land Preparation and Seedbed Refinement

Good surface drainage is critical for establishment and survival of alfalfa. Alfalfa cannot survive in waterlogged soils. Leveling to remove improperly placed dead furrows and back furrows should be done several months prior to planting alfalfa. If the field has a history of water standing in low areas, leveling and development of drainage channels should be done one to two years before planting. Development of a well-drained field frequently requires several attempts. Observing where water stands between rains is one of the best indicators of drainage needs.

Generally, the normal steps necessary for establishment of alfalfa include a primary tillage, disking, leveling, and smoothing. Primary tillage consists of moldboard plowing, chisel plowing, or deep disking. Many producers believe that plowing at least eight inches deep is essential to bury crop residue and control weeds by burying growing plants and ungerminated seeds. OSU researchers found that deep disking can be used as a substitute for moldboard or chisel plowing in fields where surface drainage is not a problem. In soils that develop a hardpan, a chisel plow is commonly used to rip through existing hardpan layers.

Shallow disking normally follows primary tillage. Disking breaks up clods and is a good tool for incorporating crop residue, lime, and fertilizer. Soil conditions may require disking several times. An ideal seedbed is firm on the surface but loose enough in the root zone to allow rapid root penetration. Disking may be followed by spring-tooth and spike-tooth harrowing to further break clods and to help smooth the field. The final operation may be a corrugated roller or cultipacker to crush the remaining clods and finish firming the soil.

Working down a seedbed should be done when there is sufficient moisture in the soil so that it crumbles when worked. There is usually a short time after each rain when soil moisture is just right. Having moist soil 1-3 inches below the surface at planting is important; however, moisture at the surface is not important. Most successful alfalfa plantings are made when the seed is planted into dry surface soil. Moisture required for germination and initial seedling growth comes from rain or irrigation after planting. If the soil is dry to a depth of 4-6 inches, it may take several inches of rain to wet the soil enough for germination of alfalfa seeds.

If preplant herbicides are used, they must be applied when the seedbed is fairly fine (no clods greater than 1/2 inch) and incorporated with a disk, operated about four inches deep. At this depth, the herbicide is uniformly distributed in the top two inches. On the surface of the final seedbed, clods should be no larger than 1/2 inch in diameter, yet it should not be powdery. A seedbed is sufficiently firm when an entire footprint is visible but sinks no deeper than an inch, or if the impression of a tractor tire sinks no deeper than the tread bar.

On certain sandy or sloping sites, it may be desirable to maintain a significant amount of crop stubble and debris on the surface. This is especially important with sandy soils that are highly susceptible to wind erosion. Preplant incorporated herbicides should not be used on these sites.

Costs for land preparation and seedbed refinement are difficult to separate clearly. Disking or using a spring tooth for seedbed preparation will frequently assist with weed control; thus, these costs should be shared by the two different activities but are often assigned to seedbed preparation. Deep tillage is relatively expensive and should not be done routinely without a specific need. Prior to deep tillage, the upper 10-15 inches of the soil profile should be examined for compacted layers. If compacted areas do not exist in this zone, tillage to this depth is usually unnecessary.

Variety Choice and Seed Quality

The choice of alfalfa variety is one of the few irreversible management decisions. That choice has a significant effect on hay yield, degree of insect and disease resistance, and stand longevity, all of which affect profits. Once the seeds are planted, however, the variety cannot be changed.

Young alfalfa seedlings can fall prey to a host of insects and diseases. Host plant pest resistance, when available in adapted varieties, is the best way to combat these problems. Seedling stands are particularly vulnerable to aphids and root rots during the first few months. These pests can destroy new stands; however, multiple-pest-resistant varieties withstand greater numbers of insects (or disease infection) without retarded growth or dead plants. In addition to the benefits during stand establishment, genetic resistance also has long-term economic benefits. One or two fewer insecticide applications may be required each year, and decreased pest stress on resistant varieties results in longer stand life.

Purchasing high quality alfalfa seed is a good investment. Cheap seed may germinate poorly, contain small or shriveled seeds, and may be contaminated with weed seeds and trash. All these factors contribute to stand failures. Consequently, buying cheap seed, while appearing to save a few dollars per acre during establishment, may actually cost the producer several thousand dollars because of reduced stand life and yield. For starters, more low-quality seed than high-quality seed is necessary to establish a good stand. Ten pounds per acre of high-germination, clean seed should be adequate, whereas 20 pounds per acre of low-germination seed containing a high percentage of weed seeds and foreign material may be required to produce the same amount of alfalfa.

Literally thousands of varieties and experimental strains have been developed, and about 100 varieties are released each year. It is no wonder then, that producers are frequently uncertain about variety choice. Some varities differ from others very little, and most are not well adapted to Oklahoma. The vast majority of alfalfa varieties were developed since 1980. Of the many varieties released each year, we test those that have potential for use in the state. In Oklahoma, we have tested almost 400 alfalfa varieties and experimental strains since the mid-1970s. Alfalfa seed companies submit about 15 new strains in addition to about 15 newly released varieties every year for tests in Oklahoma.

Costs associated with variety choice, seed quality, and planting rate are closely interrelated and cannot realistically be considered singly. Frequently, seed costs are assumed to be the major cost incurred by producers. However, when the total cost of establishing alfalfa is considered, using an improved pest-resistant variety would represent about 13 percent of the total investment. (See "Stand Establishment Budget," page 40.) Using high-quality seed would cost $30 per acre (12 pounds at $2.50 a pound). Using cheaper seed would reduce establishment costs by about $5.00. For example, a cheaper seed may cost only $1.25 per pound, but the planting rate will need to be increased to 20 pounds per acre to compensate for inferior quality. The short-term savings would be $5, which may be lost each year in reduced yield.

Table 3-1 is a cost and earnings comparison of high-quality seed of a proven variety and low-quality seed of an unknown (but probably inferior) variety. The short-term savings of $5 per acre resulted in an estimated loss of $200 per acre for a stand life of five years. This comparison is based on many years of observations of varieties and seed quality and does not include the added profits associated with longer stand life of proven varieties.

Variety Test Results for Oklahoma

Personnel in the Plant and Soil Sciences Department through the Oklahoma Agricultural Experiment and Cooperative Extension Service, conduct alfalfa variety evaluations throughout the state to assist producers with decisions related to variety choices. Varieties are planted in replicated small plots, usually at research stations but occasionally in commercial alfalfa fields. Each plot is harvested and weighed at every cutting for at least three years. Each year, results of alfalfa variety tests are published and a recommended list is updated with descriptions of how they performed in Oklahoma.

The most recent summary of alfalfa variety performance in Oklahoma can be found at www.agr.okstate.edu/alfalfa/var-test/alf-var.html. That site includes a summary of recent testing and a recommended varieties list. It

Table 3-1 Cost and earnings comparisons for using a proven seed variety versus an unknown variety

Seed Source	Seed Cost	Planting Rate	Seed Cost	Yield	Earnings with $80/ton Hay	
					Yearly	5-year
	$/lb.	lb./acre	$/acre	tons/acre	$/acre	$/acre
Proven Variety	$ 2.50	12	$30	4.5	$360	$1800
Unknown Variety	$1.25	20	$25	4.0	$320	$1600
(Difference)			$ 5	0.5	$ 40	$ 200

also includes details of yields of experimental strains and released varieties in tests, showing yields for individual cuttings and total yields for a particular year, and a total over years of the test.

The recommended list of varieties includes those that have performed very well, and they have been tested for at least 10 or 12 test-years. This means each variety has been tested for up to three years at several sites. These varieties have the pest resistance necessary for Oklahoma, and it is highly likely these relatively new varieties will continue to do well.

Seed Inoculation

Alfalfa that is high in protein requires large amounts of nitrogen. Alfalfa can convert atmospheric nitrogen into a usable form if the roots have effective nodules. Nodules are the result of an infection by an effective strain of bacteria (*Rhizobium meliloti*).

Alfalfa seed should *always* be inoculated with live *Rhizobium* bacteria, specific for alfalfa. In some fields, with a history of alfalfa or sweetclover, alfalfa may not benefit from inoculation, but it is difficult to identify those fields before planting. After emergence, inoculation is risky, difficult, and expensive. Many strains of rhizobia are present in soil, and some may form nodules on alfalfa roots, but not all nodules fix nitrogen.

Certain brands of alfalfa seed are pre-inoculated (with or without lime coating). Two types of commercial inoculants are popular for on-farm application. One type of inoculant has a dry clay sticking agent and requires no wetting of the seeds. Seeds should be mixed thoroughly with inoculant. Peat-based inoculants need a sticker to help nodule-forming bacteria adhere to seeds. Commercial preparations of stickers and *Rhizobium* are available from inoculant manufacturers and do an excellent job. Some preparations contain up to 20 times the previously recommended number of bacteria. Closely following manufacturer's instructions normally produces the best results.

An alternative to commercial stickers for peat-base inoculants is to use milk or a water solution containing 10-20 percent table syrup or sugar. One pint is sufficient sticker for a bushel of seed. Moisten all seeds (in a concrete mixer, if possible), then add the inoculant. If the mixture is still too moist, add more inoculant, finely ground limestone, or powdery dry soil.

Heat, direct sunlight, and drying are all detrimental to the survival of rhizobia. For this reason, it is important to store inoculant in a cool place. Even with the large amounts of rhizobia initially applied, many bacteria may die during prolonged storage. Expiration dates are printed on inoculant packets and pre-inoculated seed tags. The date indicates when most of the bacteria will have died under normal storage conditions. Properly inoculated seed have thousands of bacteria per seed. Only one bacterium is needed to infest a seedling's root. Bacteria on seed in hot soil die a few at a time; nevertheless, even after 2 or 3 weeks there are usually enough live bacteria remaining to be effective.

If there are questions about the viability of bacteria on inoculated seed due to the length of storage and storage conditions, then seed should be reinoculated. For lime-coated seed, do not use water to moisten; fresh inoculant can be applied with mineral oil as a sticker (1/2 ounce of mineral oil per pound of seed).

Inoculant is normally included with higher priced seed. Cost for preinoculated seed is about five cents per pound more than comparable raw seed. Inoculant costs about a dollar per acre, if applied by the grower. Legumes can establish and survive without nitrogen-fixing bacteria, but plants cannot fix nitrogen. This means that without added nitrogen, plants will have a yellowish appearance and yields will be low. With high rates of nitrogen fertilizer application, uninoculated stands can be productive. Since inoculation is easy and cheap, it is probably the best insurance a farmer can buy. (For additional discussions see Chapter 4, "Fertilizing Alfalfa," page 41.)

Planting Dates and Rates

Fall Planting. In Oklahoma, alfalfa should be planted in late August and early September. This allows seedling plants to develop roots during the fall and be capable of maximum production the following summer. Plantings can be extended into early October if a stand is irrigated immediately after planting to assure quick germination and emergence. In central Oklahoma, plants that emerge after early October may not have adequate root development to survive the winter. The ideal time for stand establishment in the panhandle and northwest part of the state does not extend as late, and in the southeast plantings may be a little later. A good rule of thumb is that alfalfa plants with five leaves before the first hard freeze (20ºF) will survive the winter. One can expect 4-5 tons per acre of weed-free hay in the first season from alfalfa planted in early September that is kept pest free. See Chapter 2, "Insect Management" and "Weed Management Practices for Fall-Planted Alfalfa" for details.

Spring Planting. In Oklahoma spring-planted alfalfa is usually not recommended since it is more risky than fall plantings. This is primarily due to more problems associated with strong drying winds, insects, weeds, and intense rains that tend to crust the soil. With spring establishment, planting between mid-March and mid-April is critical. This allows seedlings enough time to develop good root systems prior to the onset of high temperatures (above 90ºF). The use of multiple-pest resistant varieties, excellent seedbeds, and preplant incorporated herbicides are all critical with spring plantings. Spring planting is more likely to be successful in the eastern half of the state where rainfall is higher, and it can be successful statewide if irrigation is used. One should expect only one or two cuttings during the first summer from spring-planted alfalfa stands. Even in subsequent years, yields for spring-planted stands tend to be lower than those established in late summer. See Chapter 2, "Weed Management of Spring-Planted Alfalfa."

Whether planting in spring or fall, use 10-15 pounds per acre of pure live seed. Planting 10 pounds per acre of good alfalfa seed is equivalent to approximately 42 seeds per square foot, and proper planting of 10 pounds of seed per acre into a well-prepared seedbed should result in emergence of 25-30 plants per square foot. Most stands thin naturally during the first year to about 15-20 plants per square foot. Plant density will continue to decline and eventually stabilize at 5-8 plants per square foot in a full stand (25-35 stems per square foot).

Seed Placement and Equipment Options

Planting depth is critical to germination, seedling emergence, and root development. Ideally, seeds should be placed 1/2 to 3/4 inch below the soil surface. Seed placed on the surface of a freshly developed, firm, mellow seedbed and then pressed with a roller or press wheel gives the best placement. Either a combination drop seeder and tandem packer roller (Brillion seeder, for example) or a grain drill with a small-seeded legume box is the most reliable equipment for planting alfalfa. If a grain drill is used that opens a furrow too deep for alfalfa seed, it is best to connect the drop tubes behind the openers and in front of a press wheel. Rolling the site is advisable after planting with a drill. When drop tubes are allowed to swing from side to side and only a small part of the seed is pressed into the soil, only the pressed seed germinates and develops into productive plants.

Placing the correct amount of seed at the proper depth in firm contact with the soil is the prime objective when planting alfalfa. A good way to reduce the cost of establishing alfalfa is to use only the amount of seed necessary and place it in a good environment.

This means that equipment must be properly calibrated to apply the correct amount. Planting insufficient amounts of seed increases the risk of stand failure, while planting too much seed is expensive and obviously wasteful. High planting rates are not good substitutes for poor seedbed preparation.

The following are common types of equipment used for successful alfalfa establishment.

Specialized drills have a box for small seeds and disk openers with depth bands to accurately place the seed 1/2 to 3/4 inch deep. Packer wheels firm soil over and around seeds. This type of drill is especially good on very firm seedbeds.

Double corrugated roller seeders drop the seed between corrugated rollers. The first roller breaks small clods and firms the seedbed. The second roller splits the ridges made by the first roller, covers the seed, and provides additional firming of the soil. While these are considered the best alfalfa seeders for most conditions, they may leave sandy sites vulnerable to wind erosion.

Grain drills, equipped with small-seed attachments, can accurately meter alfalfa seed. The major problem in using grain drills is controlling seed placement depth. If the furrow created by the drill is too deep, rain can wash soil into the furrow and cover alfalfa seeds excessively. Few seeds left on top of the soil develop into vigorous plants, even under ideal conditions. Allowing seed-drop tubes to wave from side to side leaves many seeds on the soil surface. Tubes can be tied so that seeds fall in front of press wheels; otherwise, rolling after the planter in a separate operation helps improve emergence percentages.

Pneumatic seeders, mounted on flotation-wheeled vehicles, can sow alfalfa fields rapidly and accurately. Seed is metered from a hopper and carried through tubes along booms (20-50 feet long) with air. These machines work well on fluffy dry sandy soils that cannot be firmed by rolling. Seed is blown onto the soil from delivery tubes spaced 6-12 inches along the booms. Lightly packing, dragging a chain, or harrowing covers seed. The main advantage to this type of seeder is the rapid speed they can travel. Producers can plant several acres per minute, which may be important, such as just before a predicted rain.

Aerial planting onto freshly prepared seedbeds is another method used to plant alfalfa with good success, especially in fluffy seedbeds. Aerial applicators, experienced in planting alfalfa, can make an important difference between success and failure. With broadcast planting, two passes in a crossing pattern may be necessary for uniform coverage. Rolling the fields after aerial planting is advisable.

No-till or minimum-tillage drills can do a good job of placing alfalfa seed at the correct depth. When establishing alfalfa on steep slopes or otherwise erosive or shallow soils, this type of drill is best.

When it is impossible to prepare a firm seedbed due to excessively dry conditions, dusting-in the seed is an alternative. The bottom ends of the flexible seed tubes should be removed from the drill shanks and tied so that seed drops on the surface of the shallow furrow. A drag chain may be used to cover the seed with soil. Rainfall then firms the soil. A major risk of this establishment method is that it is dependent on receiving a soaking rain by early October.

Pest Control

Alfalfa plants are continually subjected to pest stresses. An effective integrated pest control program is essential for full stand establishment, productivity, and profitability of alfalfa. Integrated pest management should be comprehensive and targeted at the most important insect, disease, and weed problems.

Insects begin attacking alfalfa plants at emergence. Frequent scouting of new stands is essential for good insect control. Grasshoppers, armyworms, cutworms, and other general feeders can infest a new stand in a few days. Timely application of insecticides is the only reliable method of control. Spotted alfalfa aphids build up during the fall on seedling alfalfa. Blue alfalfa aphids are present nearly every spring. Using well-adapted, resistant varieties, and good cultural practices that encourage rapid growth provide the best controls for aphid infestations.

Weeds in new alfalfa stands are a major concern. They can interfere with the planting operation and compete with seedlings for nutrients, water, and light. Weeds can reduce forage quality and yield of first-cut hay. In some cases weeds cause stand failures.

Diseases, such as damping off and root rots, are sometimes problems with alfalfa stand establishment. Fungicidal treatments, applied to seed or sprayed on seedlings, are effective for a short time and may make the difference between successful stand establishment and failure. Genetic resistance in conjunction with crop rotation, good land preparation practices, and good seedbed preparation are long-lasting control measures. Root rots are most commonly found in soils that are wet for prolonged periods; therefore, correcting drainage problems before planting is an excellent disease prevention measure.

See Chapter 2, "Pests and Pest Management," for detailed discussions of each group of pests.

Crop Rotations

One of the most frequently asked questions about alfalfa production in Oklahoma is "How soon can alfalfa be planted following alfalfa?" There is no single answer that is appropriate for all conditions. Many producers believe the most reliable amount of time to leave fields out of alfalfa before reestablishing is the number of years the stand lasted. If a stand lasted six years—leave it out for six years. Currently**, at least a 2-year rotation to another crop is recommended.** Increasing rotation time between alfalfa stands minimizes most problems.

Alfalfa can be replanted in the same year in some situations but is not recommended because of:

- Autotoxicity (alfalfa seedlings inhibited by alfalfa residues in the soil)
- Depleted soil moisture
- Soilborne insects and diseases from the previous alfalfa crop
- Nutrient deficiency and pH problems
- Drainage problems

Many studies indicate that alfalfa can be reestablished successfully following alfalfa. Most reports of problems with autotoxicity are from spring-planted field studies where top growth of alfalfa was incorporated into the soil and alfalfa replanted immediately. Assuming little foliage was plowed under due to a thin stand, the importance of autotoxicity is reduced greatly.

Under some circumstances good producers can have success with alfalfa following alfalfa immediately with special attention:

- Plentiful rainfall or irrigation between alfalfa stands can alleviate problems with dry soil profiles.
- Deep moldboard plowing can assist with removing many of the insects and pathogens from the area where seedlings will grow.
- Application and incorporation of needed fertilizer and lime before planting back to alfalfa can eliminate nutrient deficiencies.
- Correction of drainage problems between stands.

In Oklahoma, there are only a few good rotational crops for alfalfa. The best rotational crops following alfalfa are cereal crops and annual forage grasses. Small grains can benefit from nitrogen released after alfalfa is plowed. Corn and sorghum could also follow alfalfa in those areas where rainfall is adequate or where irrigation is available.

Yield improvement of cereal crops following alfalfa has long been recognized. Much of this is related to nitrogen (N) fixation by alfalfa. The amount of nitrogen plowed down is highly variable and depends on the time of the season and the amount of nitrogen-rich top growth at the time of tillage. About 25 percent of the incorporated nitrogen associated with plowing down alfalfa is recovered during the next crop year.

Herbicide Residue Problems Following Alfalfa

There are crop planting restrictions following use of herbicides on crops grown in rotation with alfalfa. These restrictions are listed on the labels of herbicides and need to be followed to avoid injury to crops following herbicide applications. Some examples of replanting restrictions listed on herbicides used in alfalfa at the time of this writing follow. For updates on labels, one should check the World Wide Web at www.cdms.net.

- Karmex DF and Sinbar — Unless otherwise directed, do not replant treated areas to any crop within two years after last application, as injury may result.
- Treflan EC — In areas that receive less than 20 inches of water annually (rainfall + irrigation) to produce a crop, do not plant proso millet, sorghum (milo), oats, or small seeded forage grasses for 18 months.
- Velpar — Do not replant treated areas to any crop within two years after treatment, as crop injury may result (12 months for corn).
- Pursuit — Soybeans, peanuts, and IMI-corn can be planted any time; and alfalfa, rye, and wheat can be planted four months after treatment. Longer restrictions for other crops and vegetables exist, so see label for rotational restrictions.

The crop preceding alfalfa is critical for alfalfa stand establishment. It should be an annual cool-season grass to allow sufficient time for preparation of a good seedbed. Harvesting a small grain crop in June usually allows adequate time for seedbed preparation for an early September alfalfa planting. Using soybean, peanut, or other legume species just before or just after alfalfa is usually avoided because they are ineffective in reducing buildup of disease organisms.

Herbicide Residue Problems Preceding Alfalfa

In Oklahoma, rotational crop restrictions exist for alfalfa on many herbicides used on other crops (Table 3-2). The reason for these restrictions is that there may still be enough herbicide residue in the soil to injure subsequent crops. Damage (stunting)

Table 3-2. Examples of planting restrictions for alfalfa following use of herbicides in previous crop

Previous Crop	Herbicide	Restriction	Previous Crop	Herbicide	Restriction
Wheat	GLEAN	Field	Soybean	PURSUIT	18 months
		Bioassay**	Soybean	SCEPTER	18 months
Wheat	AMBER	Field	Corn	ACCENT	12 months
		Bioassay**	Corn	BEACON	8 months
Wheat	FINESSE	Field	Alfalfa	PURSUIT	9 months
		Bioassay**	Alfalfa	SINBAR	24 months
Wheat	ALLY	34 months	Alfalfa	VELPAR	24 months

**Field Bioassay means planting alfalfa and observing it to see that it emerges and grows normally.

of newly-planted alfalfa is not uncommon in Oklahoma fields where persistent herbicides such as GLEAN and AMBER were used for weed control in wheat the previous spring.

This has been particularly evident after dry summers following herbicide application. **To be safe, producers should always read and follow crop rotation restrictions on herbicide labels.** This includes keeping accurate records of:

- What chemical was applied
- When it was applied
- How much was applied

Stand Establishment Budget

The successful establishment of alfalfa is usually expensive. Total costs in Oklahoma vary widely, depending on needs of individual fields. Cost estimates normally run from less than $100 per acre to over $150 per acre. The high overall cost is an important reason to perform all the necessary activities correctly, in a timely fashion. Omitting steps

Table 3-3. Alfalfa stand establishment costs per acre, based on custom rates

Item or Activity	Low $ Estimate	High $ Estimate	Comments & Conditions
Soil Fertility and pH			
Soil Test	—	–	$8/sample - negligible
Nitrogen	0	4	20 lb. @ $0.20/lb.
Phosphorus	0	18	100 lb. @ $0.18/lb.
Potassium	0	10	100 lb. @ $0.10/lb.
Lime	0	60	3 tons @ $20/ton (applied)
Fertilizer Application	0	5	
Land Preparation			
Deep Tillage	0	12	Moldboard ($12), Chisel ($9), Disk ($6)
Disk	5	10	Incorporate fertilizer and break clods
Level & Drain	5	15	Depends on needs
Seedbed Preparation			
Shallow Disk (1 time)	5	7	Includes some weed control
Spring Tooth (1 time)	4	8	Includes some weed control
Spike Harrow (2 times)	4	8	
Cultipacker	0	7	
Seed			
(Includes Variety Choice, Seed Quality, Planting Rate, & Inoculation)	20	30	See “Variety Choice and Seed Quality” in this chapter
Planting	5	8	
Pest Control			
Herbicide			
Weedy Grasses	0	15	1 postemergent application
Broadleaf Weeds	0	8	1 postemergent application
Insecticide	0	8	1 application
Fungicide	0	0	Included with variety & seed
TOTAL	$ 48	$233	$80 to $100 is usual range

may contribute to stand failure or a poor stand and risk the loss of the other parts of the investment.

Table 3-3 lists a range of costs for the major activities. Costs for any particular farm may be more or less expensive. The low estimates indicate the least expenditures that a grower could reasonably expect. If the expected costs are similar to the high estimates for nearly all categories, perhaps another site should be considered, where fewer inputs are required. Note that these estimates represent costs reported for custom work. A farmer conducting a particular activity may want to break the estimate into components of labor, equipment depreciation, interest, etc. Normally, little difference in cost should be noticed.

Special Considerations

The following topics are not necessarily part of normal alfalfa stand establishment in Oklahoma. However, they are critical to many individual producers as indicated by the number of times these questions are directed to extension and research staff.

Question: Can thin stands be thickened?

Answer: Very thin first-year stands can sometimes be thickened. This refers to stands with large bare spots and areas with only 3-4 seedlings per square foot.

Thickening old (two or more years old) thin stands is **rarely successful**. Attempts to plant alfalfa into old, thin stands usually result in few, if any, new seedlings becoming productive plants. Before reseeding a thin stand, reasons for the thin stand should be evaluated and corrected.

Seedlings cannot compete with mature plants for nutrients, water, and light. In addition, seedlings are sensitive to pests that build up in and on old plants in established stands. If an old stand has thinned to the point that it is not productive, the field should be rotated to another crop for several years before reestablishing alfalfa.

"Drowned-out" spots: There is a temptation to replant drowned-out spots. This is justified *only* if the reasons for the wet spots are corrected. After correcting drainage and preparing a good seedbed, alfalfa can be established successfully. Trying to fill in wet spots with new alfalfa without correcting the problem usually results in another stand failure.

Thin seedling stands: There is little danger of autotoxicity problems in thin stands less than a year old. If the reason for a thin stand from a fall planting was poor seedbed preparation, late planting, or wash-out (blow-out), then overseeding into thin spots in early spring could thicken areas with fewer than five plants per square foot. Likewise, thin spring-planted stands can be thickened up the following fall when there is almost no danger of autotoxicity. Again, the problem that caused the original poor stand must be corrected. Even after a few months, soils become hard and weeds encroach, normally resulting in poor seedbeds.

Question: Will companion crops (or nurse crops) help with alfalfa stand establishment?

***Answer*:** Only use companion crops that do not crowd out alfalfa. Planting a small grain with alfalfa during establishment is not usually recommended under Oklahoma conditions. In fact these crops and winter weeds should be controlled with herbicides, since they compete for moisture and light, resulting in reduced yield and quality of alfalfa. They may cause complete stand loss. On sandy soils, a thin stand of a grass such as German millet is a good way to protect alfalfa seedlings from wind-blown sand. German millet can be planted (at five pounds per acre) before alfalfa or with it. Planting other non-winter hardy crops, such as sorghum-sudangrass or spring oats, 3-4 feet apart in east-west rows is another good option. Thin stands of summer weeds can also serve as a companion crop. Because these plants die in the winter, they are not competitive with alfalfa during the subsequent spring. Some producers have successfully planted turnips with fall-planted alfalfa and use the turnips for livestock grazing in the winter and spring.

Question: Does no-till establishment of alfalfa have a place in Oklahoma?

***Answer*:** It is considered very risky to attempt no-till establishment of alfalfa in Oklahoma. For this reason, little no-till is practiced. No-till requires even more long-range planning than conventional establishment. Land shaping for improved drainage must be done prior to establishing the previous crop. In addition, fertilizer and lime for the alfalfa crop should be applied and incorporated before the previous crop. Application of lime and phosphorous to the soil surface is not as effective; thus, more must be applied.

When planting alfalfa into existing vegetation, control of weeds and insects is also more difficult. More rain may be required for alfalfa emergence with no-till practices since the existing plants will be using water.

No-till planting of alfalfa into established sod is not usually successful. If alfalfa is planted into fescue or bermudagrass sod, bands of sod must be killed. The bands can be 6-8 inches wide and spaced every 20-40 inches. Plants can be killed with herbicides or certain minimum-tillage drills. Planting alfalfa into fescue or bermudagrass sod is also difficult because of problems related to insufficient water. When planting into sod in the fall, the soil may be dry because of water usage by the grass during summer. Interseeding alfalfa in the spring puts alfalfa seedlings at a disadvantage because of the strong competition with the established grass.

The best results with no-till alfalfa establishment have been into stubble of cool-season annual crops such as wheat. Summer weeds and volunteer wheat plants can be a major problem, and controlling them with herbicides may be excessively expensive. This is especially true with above-average summer rainfall. Alfalfa can also be interseeded into German millet stubble if the millet grows for only a few weeks and is harvested for hay just before planting alfalfa. The millet's fine stems do not interfere with most common alfalfa planters. The short growth period for millet does not dry the soil as much as other warm season crops. Millet regrows very little after cutting and offers little competition to alfalfa seedlings.

Question: How much nitrogen can alfalfa fix?

Answer: Effective nodules on alfalfa, generally pink to deep red on the inside, can fix several hundred pounds of nitrogen per acre each season. Assume a five-ton-per-acre yield of 20 percent protein hay. This amounts to a ton (or 2,000 pounds) of protein. Protein contains about 16 percent nitrogen. This means that the plants fixed about 320 pounds of nitrogen per acre. Higher yields or higher average protein concentration would obviously require more nitrogen fixation.

Chapter 4
Fertilizing Alfalfa

Soil testing is the only way to determine the fertility status and pH of your soil. Soil test readings (in pounds per acre) of at least 65 for phosphorus (P) and 350 for potassium (K), along with a soil pH near seven, are considered essential for alfalfa production. Yield of alfalfa will be significantly decreased and productive stand life shortened if these essential nutrients are inadequate, or if soil is more than slightly acidic (<pH 6.5). Soil pH needs to be near neutral (pH 7) so *Rhizobium* bacteria can fix nitrogen for use by the alfalfa plant. See www.agr.okstate.edu/alfalfa/webnews/sf1-98.htm on the Web to learn how to obtain a reliable soil sample.

An evaluation of Oklahoma alfalfa production fields in 1995 showed that 75 percent of the alfalfa fields had low pH or were deficient in either P_2O_5 or K_2O, or both. During 2000, 92 percent of the 434 soil samples analyzed for alfalfa production by the Soil, Water, and Forage Analytical Laboratory at OSU needed lime, P, or K for good production (Fig. 4-1). Only eight percent needed none of the three, and 65 percent needed one or two of them. To ensure proper pH and adequate fertility, have a soil test performed and apply enough lime to neutralize the soil. Also apply enough phosphorous and potassium to satisfy the crop's needs before planting alfalfa. For best results, both lime and fertilizer should be incorporated into the top six inches of soil.

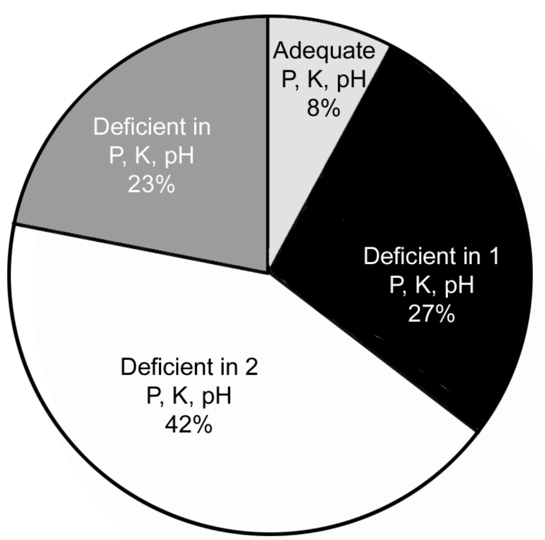

Figure 4-1. Percentage of alfalfa soil samples that were adequate or deficient in P, K, or pH. From samples analyzed by SWFAL in 2000

High-yielding alfalfa removes large amounts of nutrients from the soil (Table 4-1). Through the normal process of soil weathering, soils are able to supply a certain amount of the required nutrients annually according to their chemical and physical makeup. Monitoring the nutrient status of your soil through testing is the best way to know what nutrients are being naturally supplied and how much fertilizer supplementation is needed to keep alfalfa productive.

Liming

Alfalfa is not as tolerant of acid soils as wheat and some other crops. Soil pH must be maintained above 6.2 to ensure an environment favorable for nitrogen-fixing bacteria. Wheat grows well at a soil pH of 5.5, but alfalfa production can be reduced by 50 percent at pH 5.5, and stand failure is likely at a soil pH of 5.0. Alfalfa yield and quality decrease when production is attempted in acid soil.

Whenever the soil pH is below 6.2, a minimum of one ton ECCE (effective calcium carbonate equivalent) lime should be applied and incorporated 4-6 inches deep prior to planting. Depending on the level of acidity, loamy and clay-type soils may require several tons of aglime per acre. Since it takes several months for lime to react with the soil, it is best to apply lime at least a year before planting alfalfa. A soil reserve of about 3-5 tons of lime is required to meet the needs of a five-ton alfalfa yield for 6-10 years without a drastic decline in soil pH.

Given today's high production costs, attempting to establish alfalfa without first

Table 4-1. Approximate nutrient content and removal in five tons of alfalfa hay

Nutrient	Average Composition (%)	Pounds in 5 Tons of Hay
N (Nitrogen)	3.0	300
P_2O_5 (Phosphorus)	0.55	54
K_2O (Potassium)	2.5	250
Ca (Calcium)	1.2	120
Mg (Magnesium)	0.4	42
S (Sulfur)	0.28	28

having the surface soil (to six inches deep) tested is unsound and may be a costly mistake. Having a nonacid subsoil cannot substitute for the need to lime an acid surface soil, since most of the nitrogen-fixing bacterial activity is in the upper six inches of soil. Even though alfalfa draws heavily on the basic mineral elements (K, Ca, Mg) in the soil, applying the proper rate of lime before planting to adjust the pH to seven should provide an adequate supply of elements for the life of the stand.

Fertilization

Nitrogen (N)

Some nitrogen (20-30 pounds per acre) is required for establishment of seedling alfalfa. This amount of nitrogen is often available in September in fields that have lain fallow the summer after a June wheat harvest. Once alfalfa seedlings form nodules on their roots, they can fix their own nitrogen from the atmosphere, so no more nitrogen needs to be applied during the life of the stand. Nitrogen fixation is the result of a symbiotic activity of alfalfa and *Rhizobium* bacteria. For the symbiosis to occur, it is important that properly inoculated seed be used and that the nitrogen-fixing bacteria become active. Response to nitrogen fertilizer after alfalfa is established is a sign that the soil conditions are too acidic or that nitrogen-fixing bacteria are absent. A soil test can determine if acidity is the problem, but neither acidity nor inoculation failure can be corrected after the alfalfa is planted.

Phosphorus (P) and Potassium (K)

As shown in Table 4-1, harvesting five tons per acre of alfalfa removes more than 50 pounds per acre of P_2O_5 and 250 pounds per acre of K_2O each year. Soils usually can supply some of these nutrients, but phosphorus or potassium fertilizer (or both) often needs to be applied before and during the life of the stand.

The fertility levels of P and K and the needs for lime in sandy soil change more rapidly under alfalfa production than with other crops. The best way to determine how much phosphorus (P_2O_5) and potassium (K_2O) to apply is to test the soil. Results of a soil test are calibrated to give a "Soil Test Index" that

Table 4-2. Phosphorus (P_2O_5) and potassium (K_2O) soil test calibrations*

P_2O_5 Soil Test Index	Deficiency	K_2O Soil Test Index	Deficiency
	lb./acre P_2O_5		lb./acre K_2O
0	200	0	280
10	150	75	210
20	100	125	140
40	60	200	80
65	None	300	25
-	-	350	None

* Calibrations only apply to OSU soil tests by the Soil, Water, and Forage Analytical Laboratory

relates to the amount needed in pounds per acre of P_2O_5 or K_2O (Table 4-2). Note that phosphorus and potassium fertilizers are not needed at soil test values of 65 or greater for phosphorus and 350 or greater for potassium. Because these nutrients (P and K) are considered immobile in the soil — that is, they react with the soil and do not migrate with the soil's moisture content — the most efficient way to get them into the rooting zone is to incorporate them before planting. Applying additional phosphorus and potassium fertilizers to the surface of existing stands is somewhat less efficient, but it is necessary in most fields for profitable alfalfa production.

Phosphorus (P) deficiencies are best corrected by applying and incorporating a three-year supply of fertilizer in the summer before fall planting. Soil fertility levels should then be monitored through annual soil testing, and any additional P should be added following the second or third year of production from November to January, before early spring growth. Best response to surface-applied P is usually obtained in the first cutting. Good surface moisture in the spring results in P uptake by surface roots. Starting the follow-up applications of P in the second year also allows time for some movement of P through soil disturbances caused by insects, cattle, machinery, freezing, etc.

Potassium (K) deficiencies are best corrected by applying only enough for one year because alfalfa will take up more than needed when large amounts are available (luxury consumption). After alfalfa is established, soil should be tested annually after the second year, and K should be applied as needed from November to January, before early spring growth.

Secondary and Micronutrients

Deficiencies of the secondary elements (calcium, magnesium, and sulfur) and micronutrients (iron, zinc, manganese, copper, boron, molybdenum, and chlorine) are usually not a problem with alfalfa production in Oklahoma. Some magnesium, boron, sulfur, and zinc deficiencies have been reported in the extreme southeastern part of Oklahoma. Because irrigation waters in Oklahoma are high in sulfur, response to sulfur-containing fertilizers can only be expected under high-yielding dryland production.

Special fertilizers containing secondary and micronutrients should not be applied to alfalfa unless there is strong evidence of a deficiency. Deficiencies may be confirmed by observation of stunted yellow plants, a reliable soil test, or application of a fertilizer containing a single nutrient to a small area of the field and observing the response. However, it is critical that soil pH and levels of phosphorus and potassium have been corrected before trying to confirm a secondary or micronutrient deficiency.

Alfalfa Yield Response to Methods and Rates of Applied Phosphorus

The results of a six-year test illustrate the importance of phosphorus fertilization when alfalfa was established in a phosphorus-deficient soil, and weeds were controlled with herbicides (see Table 4-3). Based on OSU soil test recommendations, the soil at this site needed no nitrogen, about 80 pounds per acre of P_2O_5, no K_2O, and no lime.

Alfalfa's response to phosphorus fertilizer the first year increased as applied phosphorus increased, with maximum yield of seven tons per acre at the 600 pounds per acre of P_2O_5 rate (Table 4-4). In the sixth year of the trial, yield response to the initial 600 pounds per acre of P_2O_5 treatment was lower (6.55 tons

Table 4-3. Initial soil test of the entire experimental area

NO_3-N	P_2O_5	K_2O	pH
	lb./acre		
27.2	30.2	326	6.6

NO_3-N by 2M KCl extractant;
P, K extracted by Mehlich III; and
pH was measured in 1:1 soil-water suspension.

Table 4-4. Alfalfa response to surface broadcast phosphorus as diammonium phosphate, 18-46-0

First Year P_2O_5 Rate	Year-1 Yield	6-year Total P_2O_5 Applied	Year-6 Yield	Average Yield over 6 years
lb./acre	tons/acre	lb./acre	tons/acre	lb./acre
0	4.9	0	3.6	4.9
100	5.4	600	4.4	5.5
200	4.9	600	4.4	5.7
600	6.1	600	3.8	5.7

per acre) in relation to plots that had received annual and biennial phosphorus fertilization (Table 4-4). Despite the drop in yield response late in the experiment to the 600 pounds per acre of P_2O_5, this treatment still yielded the highest of all broadcast treatments of 18-46-0 over the six years of the experiment (Table 4-5). Every year, plots receiving no phosphorus produced the lowest yield.

Additionally, subsurface banding (knifing) of liquid phosphorus stabilized alfalfa yields over the length of the trial, resulting in the highest yield over the six years with these treatments (Table 4-5). These responses support the theory that banding of P_2O_5 increases availability by placing the nutrient in closer proximity to plant roots and minimizing soil-fertilizer reactions, maintaining availability for a longer period of time. Supplying a large amount (600 pounds per acre) of incorporated phosphorus before alfalfa establishment in a high-yielding (e.g., irrigated) environment provides maximum response because plant density is high. As stands age and plant density decreases, availability of fertilizer phosphorus decreases by reactions with soil, removal by crop uptake, and poorer extraction by a less dense root system. Smaller rates applied more frequently were better able to sustain a phosphorus-rich environment that supported higher yields in the sixth year.

Alfalfa Yield Response to Potassium and Sulfur

Three additional fertility treatments were included in the six-year study described above to evaluate the effect of 500 pounds per acre per year of K_2O, 500 pounds per acre per two years of K_2O, and 50 pounds per acre per year of sulfur, each applied along with 200 pounds per acre per two years of P_2O_5 broadcast as DAP. The potassium treatment was included to identify when blanket applications should be made in order to eliminate or minimize available potassium as a yield-limiting variable. Accordingly, the entire test site received blanket applications of 500 pounds per acre of K_2O at establishment and in years three and five.

Potassium fertilization resulted in increased yields over the length of the experi-

Table 4-5. Alfalfa yield response to P_2O_5 application as affected by application timing, placement, and form of phosphorus*

P_2O_5 Fertilizer Application	Application Method	Yield Increase During 6 Years (tons/acre)
100 lb./acre/year	Broadcast as DAP	3.40
200 lb./acre/2 years	Broadcast as DAP	4.20
600 lb./acre/6 years	Broadcast as DAP	4.70
200 lb./acre/2 years	Knifed as APP	5.80
600 lb./acre/6 years	Knifed as APP	6.80

DAP = diammonium phosphate, 18-46-0. APP = ammonium polyphosphate, 10-34-0

* Increase compared to check plots that received no P_2O_5 during the study and produced a total of 29.7 tons/acre

ment (Table 4-6). The 200 pounds per acre per two years of P_2O_5 in conjunction with 500 pounds per acre per year of K_2O yielded the highest of all treatments over the six years. This response was somewhat surprising since the initial soil test of 326 pounds per acre was near the calibrated adequate level (K>350 pounds per acre). Apparently alfalfa responds to higher levels of available soil potassium in a high-yield environment. This statistically significant response of about four tons per acre (value about $320) was from an input of an additional 1500 pounds of K_2O (cost about $165) and would merit economic consideration. It is possible that lower annual rates (e.g., 250-300 pounds K_2O per acre) might have also supported this maximum yield and that the dollar difference would have been even larger compared to the alfalfa that did not receive potassium. Sulfur fertilization only slightly affected yield over the six-year trial period.

Soil Analysis After Six Years

Final phosphorus soil test levels in alfalfa that received a single application of 600 pounds per acre of P_2O_5 (both broadcast and injected) were significantly lower than treatments receiving annual or biennial phosphorus applications (Table 4-7). Soil test phosphorus was significantly lower in the unfertilized check than for all other treatments.

As expected, the treatment receiving 500 pounds per acre per year of K_2O had the highest potassium soil test value. It should be noted that the potassium increased from 326 pounds per acre in the beginning to 650 to more than 700 in other plots that only received the initial and two subsequent 500 pounds per acre of K_2O blanket treatments (Table 4-7). This difference illustrates that K_2O builds up when applied in excess of the amount needed by the alfalfa.

Table 4-7 also confirms the tendency for pH to decrease most where yields are highest. The pH in the check plots (lowest yielding) increased from the initial 6.6-7.2 during this time. Average NO_3-N (nitrate nitrogen) was 27.2 pounds per acre in the beginning and ranged from 4.6-7.0 (approximations of zero) at the end of the six years. Observing rates of NO_3-N that low should not be of concern; in fact, most alfalfa fields have NO_3-N readings between four and ten pounds per acre after a few months of production. The alfalfa is using primarily nitrogen fixed in symbiosis with *Rhizobium* bacteria.

The positive significant response of alfalfa to both P and K at higher than currently recommended rates based on soil testing has important economic implications. If a producer is able to maximize yields over a six-year period by supplying the P fertilizer as a single event, additional profit may be realized because equipment and labor costs are decreased due to fewer fertilizer applications. However, some of the savings in fewer applications would be offset by lost interest on money used to purchase all the phosphorus at the beginning of the six-year period.

Response of Alfalfa to P Fertilizers in Thinning Stand

Seven of the phosphorus treatments in the previous experiment were compared with and without weeds (Table 4-8). To exclude weeds, herbicides were applied to control weeds in years six through eight when weeds in hay at first harvest were five percent or greater of the total forage. Weeds started to compete with alfalfa in some of the plots by the fifth year, so the fertility study was continued for three more years to obtain weed interference data.

Data collected during years six through eight of the study indicated that weeds must be controlled in thinning alfalfa stands to obtain a favorable alfalfa yield response to fertilizer. By the sixth year, increased weed production and decreased alfalfa production resulted with some of the fertilizer treatments containing nitrogen. The fertilizer treatment having the greatest impact on weed interference in the sixth year was an annual application of 100 pounds per acre of 18-46-0. This treatment had the greatest weed production and lowest alfalfa production when weeds were not controlled, but had the highest alfalfa yield when weeds were controlled.

In the seventh and eighth year, increased weed production and decreased alfalfa production resulted with all fertility treatments. Total alfalfa production from fertilized treatments in the seventh year averaged only two tons per acre when weeds were not controlled compared to six tons per acre when herbicides were used to control weeds. By the seventh year, the stem densities of alfalfa had decreased to the point that there was growing space for weeds in all plots.

In conclusion, it appears that phosphorus fertilizer can have a negative effect on alfalfa hay production in thinning stands (< 25 alfalfa stems per square foot) if weeds are not controlled, especially if the phosphorus fertilizer contains nitrogen (For weed control recommendation, see Chapter 2, "Weed Management in Established Stands with less than 20 stems per square foot"). When fertilizer is applied and weeds are not controlled, weeds respond to the fertilizer and become more competitive, thus yield of alfalfa is reduced. To maintain a productive level of alfalfa with fertilizer, it is critical that weeds are controlled as stands thin and particularly when weeds start to comprise up to five percent of the hay at first harvest.

Chapter 4
Fertilizing Alfalfa

Soil testing is the only way to determine the fertility status and pH of your soil. Soil test readings (in pounds per acre) of at least 65 for phosphorus (P) and 350 for potassium (K), along with a soil pH near seven, are considered essential for alfalfa production. Yield of alfalfa will be significantly decreased and productive stand life shortened if these essential nutrients are inadequate, or if soil is more than slightly acidic (<pH 6.5). Soil pH needs to be near neutral (pH 7) so *Rhizobium* bacteria can fix nitrogen for use by the alfalfa plant. See www.agr.okstate.edu/alfalfa/webnews/sf1-98.htm on the Web to learn how to obtain a reliable soil sample.

An evaluation of Oklahoma alfalfa production fields in 1995 showed that 75 percent of the alfalfa fields had low pH or were deficient in either P_2O_5 or K_2O, or both. During 2000, 92 percent of the 434 soil samples analyzed for alfalfa production by the Soil, Water, and Forage Analytical Laboratory at OSU needed lime, P, or K for good production (Fig. 4-1). Only eight percent needed none of the three, and 65 percent needed one or two of them. To ensure proper pH and adequate fertility, have a soil test performed and apply enough lime to neutralize the soil. Also apply enough phosphorous and potassium to satisfy the crop's needs before planting alfalfa. For best results, both lime and fertilizer should be incorporated into the top six inches of soil.

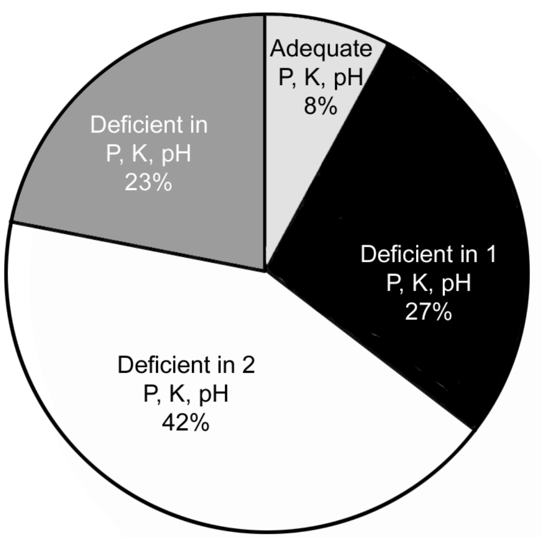

Figure 4-1. Percentage of alfalfa soil samples that were adequate or deficient in P, K, or pH. From samples analyzed by SWFAL in 2000

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Liming

Alfalfa is not as tolerant of acid soils as wheat and some other crops. Soil pH must be maintained above 6.2 to ensure an environment favorable for nitrogen-fixing bacteria. Wheat grows well at a soil pH of 5.5, but alfalfa production can be reduced by 50 percent at pH 5.5, and stand failure is likely at a soil pH of 5.0. Alfalfa yield and quality decrease when production is attempted in acid soil.

Whenever the soil pH is below 6.2, a minimum of one ton ECCE (effective calcium carbonate equivalent) lime should be applied and incorporated 4-6 inches deep prior to planting. Depending on the level of acidity, loamy and clay-type soils may require several tons of aglime per acre. Since it takes several months for lime to react with the soil, it is best to apply lime at least a year before planting alfalfa. A soil reserve of about 3-5 tons of lime is required to meet the needs of a five-ton alfalfa yield for 6-10 years without a drastic decline in soil pH.

Table 4-1. Approximate nutrient content and removal in five tons of alfalfa hay

Nutrient	Average Composition (%)	Pounds in 5 Tons of Hay
N (Nitrogen)	3.0	300
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Given today's high production costs, attempting to establish alfalfa without first having the surface soil (to six inches deep) tested is unsound and may be a costly mistake. Having a nonacid subsoil cannot substitute for the need to lime an acid surface soil, since most of the nitrogen-fixing bacterial activity is in the upper six inches of soil. Even though alfalfa draws heavily on the basic mineral elements (K, Ca, Mg) in the soil, applying the proper rate of lime before planting to adjust the pH to seven should provide an adequate supply of elements for the life of the stand.

Fertilization

Nitrogen (N)

Some nitrogen (20-30 pounds per acre) is required for establishment of seedling alfalfa. This amount of nitrogen is often available in September in fields that have lain fallow the summer after a June wheat harvest. Once alfalfa seedlings form nodules on their roots, they can fix their own nitrogen from the atmosphere, so no more nitrogen needs to be applied during the life of the stand. Nitrogen fixation is the result of a symbiotic activity of alfalfa and *Rhizobium* bacteria. For the symbiosis to occur, it is important that properly inoculated seed be used and that the nitrogen-fixing bacteria become active. Response to nitrogen fertilizer after alfalfa is established is a sign that the soil conditions are too acidic or that nitrogen-fixing bacteria are absent. A soil test can determine if acidity is the problem, but neither acidity nor inoculation failure can be corrected after the alfalfa is planted.

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crops. The best way to determine how much phosphorus (P_2O_5) and potassium (K_2O) to apply is to test the soil. Results of a soil test are calibrated to give a "Soil Test Index" that relates to the amount needed in pounds per acre of P_2O_5 or K_2O (Table 4-2). Note that phosphorus and potassium fertilizers are not needed at soil test values of 65 or greater for phosphorus and 350 or greater for potassium. Because these nutrients (P and K) are considered immobile in the soil — that is, they react with the soil and do not migrate with the soil's moisture content — the most efficient way to get them into the rooting zone is to incorporate them before planting. Applying additional phosphorus and potassium fertilizers to the surface of existing stands is somewhat less efficient, but it is necessary in most fields for profitable alfalfa production.

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Potassium (K) deficiencies are best corrected by applying only enough for one year because alfalfa will take up more than needed when large amounts are available (luxury consumption). After alfalfa is established, soil should be tested annually after the second year, and K should be applied as needed from November to January, before early spring growth.

Secondary and Micronutrients

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Alfalfa Yield Response to Methods and Rates of Applied Phosphorus

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Alfalfa's response to phosphorus fertilizer the first year increased as applied phosphorus

Table 4-3. Initial soil test of the entire experimental area

NO_3-N	P_2O_5	K_2O	pH
	lb./acre		
27.2	30.2	326	6.6

NO_3-N by 2M KCl extractant;
P, K extracted by Mehlich III; and
pH was measured in 1:1 soil-water suspension.

Table 4-4. Alfalfa response to surface broadcast phosphorus as diammonium phosphate, 18-46-0

First Year P_2O_5 Rate	Year-1 Yield	6-year Total P_2O_5 Applied	Year-6 Yield	Average Yield over 6 years
lb./acre	tons/acre	lb./acre	tons/acre	lb./acre
0	4.9	0	3.6	4.9
100	5.4	600	4.4	5.5
200	4.9	600	4.4	5.7
600	6.1	600	3.8	5.7

increased, with maximum yield of seven tons per acre at the 600 pounds per acre of P_2O_5 rate (Table 4-4). In the sixth year of the trial, yield response to the initial 600 pounds per acre of P_2O_5 treatment was lower (6.55 tons per acre) in relation to plots that had received annual and biennial phosphorus fertilization (Table 4-4). Despite the drop in yield response late in the experiment to the 600 pounds per acre of P_2O_5, this treatment still yielded the highest of all broadcast treatments of 18-46-0 over the six years of the experiment (Table 4-5). Every year, plots receiving no phosphorus produced the lowest yield.

Additionally, subsurface banding (knifing) of liquid phosphorus stabilized alfalfa yields over the length of the trial, resulting in the highest yield over the six years with these treatments (Table 4-5). These responses support the theory that banding of P_2O_5 increases availability by placing the nutrient in closer proximity to plant roots and minimizing soil-fertilizer reactions, maintaining availability for a longer period of time. Supplying a large amount (600 pounds per acre) of incorporated phosphorus before alfalfa establishment in a high-yielding (e.g., irrigated) environment provides maximum response because plant density is high. As stands age and plant density decreases, availability of fertilizer phosphorus decreases by reactions with soil, removal by crop uptake, and poorer extraction by a less dense root system. Smaller rates applied more frequently were better able to sustain a phosphorus-rich environment that supported higher yields in the sixth year.

Alfalfa Yield Response to Potassium and Sulfur

Three additional fertility treatments were included in the six-year study described above to evaluate the effect of 500 pounds per acre per year of K_2O, 500 pounds per acre per two years of K_2O, and 50 pounds per acre per year of sulfur, each applied along with 200 pounds per acre per two years of P_2O_5 broadcast as DAP. The potassium treatment was included

Table 4-5. Alfalfa yield response to P_2O_5 application as affected by application timing, placement, and form of phosphorus*

P_2O_5 Fertilizer Application	Application Method	Yield Increase During 6 Years (tons/acre)
100 lb./acre/year	Broadcast as DAP	3.40
200 lb./acre/2 years	Broadcast as DAP	4.20
600 lb./acre/6 years	Broadcast as DAP	4.70
200 lb./acre/2 years	Knifed as APP	5.80
600 lb./acre/6 years	Knifed as APP	6.80

DAP = diammonium phosphate, 18-46-0. APP = ammonium polyphosphate, 10-34-0

* Increase compared to check plots that received no P_2O_5 during the study and produced a total of 29.7 tons/acre

to identify when blanket applications should be made in order to eliminate or minimize available potassium as a yield-limiting variable. Accordingly, the entire test site received blanket applications of 500 pounds per acre of K_2O at establishment and in years three and five.

Potassium fertilization resulted in increased yields over the length of the experiment (Table 4-6). The 200 pounds per acre per two years of P_2O_5 in conjunction with 500 pounds per acre per year of K_2O yielded the highest of all treatments over the six years. This response was somewhat surprising since the initial soil test of 326 pounds per acre was near the calibrated adequate level (K>350 pounds per acre). Apparently alfalfa responds to higher levels of available soil potassium in a high-yield environment. This statistically significant response of about four tons per acre (value about $320) was from an input of an additional 1500 pounds of K_2O (cost about $165) and would merit economic consideration. It is possible that lower annual rates (e.g., 250-300 pounds K_2O per acre) might have also supported this maximum yield and that the dollar difference would have been even larger compared to the alfalfa that did not receive potassium. Sulfur fertilization only slightly affected yield over the six-year trial period.

Table 4-6. Total alfalfa yield **increases** (treatment minus check) from phosphorus, potassium, and S fertilization after six years*

Fertilizer Regime	Yield Increase over 6 years
	tons/acre
500 lb./acre of K_2O preplant, year 3, & year 5 plus 200 lb./acre/2 years of P_2O_5	4.2
50 lb./acre/year of sulfur plus 200 lb./acre/2 years of P_2O_5	5.3
500 lb./acre of K_2O each year plus 200lb./acre/2 years of P_2O_5	8.1

* Unfertilized check yield = 29.7 tons per acre total during six years.

Soil Analysis After Six Years

Final phosphorus soil test levels in alfalfa that received a single application of 600 pounds per acre of P_2O_5 (both broadcast and injected) were significantly lower than treatments receiving annual or biennial phosphorus applications (Table 4-7). Soil test phosphorus was significantly lower in the unfertilized check than for all other treatments.

As expected, the treatment receiving 500 pounds per acre per year of K_2O had the highest potassium soil test value. It should be noted that the potassium increased from 326 pounds per acre in the beginning to 650 to more than 700 in other plots that only received the initial and two subsequent 500 pounds per acre of K_2O blanket treatments (Table 4-7). This difference illustrates that K_2O builds up when applied in excess of the amount needed by the alfalfa.

Table 4-7 also confirms the tendency for pH to decrease most where yields are highest. The pH in the check plots (lowest yielding) increased from the initial 6.6-7.2 during this time. Average NO_3-N (nitrate nitrogen) was 27.2 pounds per acre in the beginning and ranged from 4.6-7.0 (approximations of zero) at the end of the six years. Observing rates of NO_3-N that low should not be of concern; in fact, most alfalfa fields have NO_3-N readings between four and ten pounds per acre after a few months of production. The alfalfa is using primarily nitrogen fixed in symbiosis with *Rhizobium* bacteria.

The positive significant response of alfalfa to both P and K at higher than currently recommended rates based on soil testing has important economic implications. If a producer is able to maximize yields over a six-year period by supplying the P fertilizer as a single event, additional profit may be realized because equipment and labor costs are decreased due

Table 4-7. Final soil tests of selected fertility treatments applied on alfalfa

Treatment	Nitrate Nitrogen	P_2O_5	K_2O	pH
	—lb./acre of nutrient extracted from soil—			
Check (no P_2O_5 added)	7.0	15.5	717	7.2
100 lb. P_2O_5 per acre per year	4.6	77.4	679	6.9
200 lb. P_2O_5 per acre per 2 years	5.5	77.6	738	6.9
600 lb. P_2O_5 per acre per 6 years	6.2	41.0	708	7.0
200 lb. P_2O_5 per acre per 2 years (knifed)	5.8	78.3	693	6.8
600 lb. P_2O_5 per acre per 6 years (knifed)	5.8	25.6	679	7.0
200 lb. P_2O_5 per acre per 2 years plus 500 lb K_2O per acre per year	5.6	59.8	1135	6.5
200 lb. P_2O_5 per acre per 2 years plus 50 lb S per acre per year	5.3	69.3	648	7.1

NO_3-N in 2M KCl extractant; P, K in Mehlich III; pH in 1:1 soil-water

All treatments, including check, received 500 lb./acre of K_2O in years 1, 3, and 5

to fewer fertilizer applications. However, some of the savings in fewer applications would be offset by lost interest on money used to purchase all the phosphorus at the beginning of the six-year period.

Response of Alfalfa to P Fertilizers in Thinning Stand

Seven of the phosphorus treatments in the previous experiment were compared with and without weeds (Table 4-8). To exclude weeds, herbicides were applied to control weeds in years six through eight when weeds in hay at first harvest were five percent or greater of the total forage. Weeds started to compete with alfalfa in some of the plots by the fifth year, so the fertility study was continued for three more years to obtain weed interference data.

Data collected during years six through eight of the study indicated that weeds must be controlled in thinning alfalfa stands to obtain a favorable alfalfa yield response to fertilizer. By the sixth year, increased weed production and decreased alfalfa production resulted with some of the fertilizer treatments containing nitrogen. The fertilizer treatment having the greatest impact on weed interference in the sixth year was an annual applica-

Table 4-8. Fertility treatments applied on alfalfa*

No P_2O_5 added during the study

Treatment applied annually

- 100 lb./acre of P_2O_5 as 18-46-0 diammonium phosphate

Treatments applied before planting and in years 3, 5, and 7

- 100 lb./acre of P_2O_5 as 0-46-0 triple superphosphate
- 200 lb./acre of P_2O_5 as 0-46-0 triple superphosphate
- 100 lb./acre of P_2O_5 as 18-46-0 diammonium phosphate
- 200 lb./acre of P_2O_5 as 18-46-0 diammonium phosphate
- 200 lb./acre of P_2O_5 as 10-34-0 ammonium polyphosphate, injected

* Each fertility treatment listed was included with and without herbicide

tion of 100 pounds per acre of 18-46-0. This treatment had the greatest weed production and lowest alfalfa production when weeds were not controlled, but had the highest alfalfa yield when weeds were controlled.

In the seventh and eighth year, increased weed production and decreased alfalfa production resulted with all fertility treatments. Total alfalfa production from fertilized treatments in the seventh year averaged only two tons per acre when weeds were not controlled compared to six tons per acre when herbicides were used to control weeds. By the seventh year, the stem densities of alfalfa had decreased to the point that there was growing space for weeds in all plots.

In conclusion, it appears that phosphorus fertilizer can have a negative effect on alfalfa hay production in thinning stands (< 25 alfalfa stems per square foot) if weeds are not controlled, especially if the phosphorus fertilizer contains nitrogen (For weed control recommendation, see Chapter 2, "Weed Management in Established Stands with less than 20 stems per square foot"). When fertilizer is applied and weeds are not controlled, weeds respond to the fertilizer and become more competitive, thus yield of alfalfa is reduced. To maintain a productive level of alfalfa with fertilizer, it is critical that weeds are controlled as stands thin and particularly when weeds start to comprise up to five percent of the hay at first harvest.

Chapter 5
Forage Yield and Quality

High forage yield, quality (nutritive value), and long stand life are normal goals of alfalfa producers. These three traits are interdependent and somewhat negatively related. High forage yield, especially for an individual harvest, frequently results in low quality because of a long interval between harvests. Attempting to obtain high quality, especially over the life of a stand, usually results in shortened stand life because the early harvesting necessary for high quality hastens stand decline. Additional information on hay yield and quality can be obtained through the Oklahoma Alfalfa Calendar on the World Wide Web at www.agr.okstate.edu/alfalfa.

To be successful, alfalfa growers should prioritize yield, quality, and stand life for each field. If high forage quality is the highest priority for a particular stand, it should be recognized that yield and stand life will be sacrificed to a certain extent. If long stand life is the highest priority for another stand, yield and quality may suffer.

Pest stresses tend to decrease both yield and quality of alfalfa. Highest quality forage is obtained from young alfalfa plants with healthy leaves attached. Foliar feeding insects consume the most succulent leaves. Leaf diseases cause damage that usually results in loss of leaf tissue. Weeds dilute forage quality, and shading by weeds may result in leaf loss of shaded alfalfa plants. Therefore, to maintain high yields and quality, pests should be controlled. (See Chapter 2, "Pest Management.")

Improving forage yield and stand life are focal points for many of the chapters in this guide. This chapter focuses on improving or maintaining forage quality by examining:

- Measures of Forage Quality
- Forage Quality and Livestock Production
- Managing for Quality and Yield

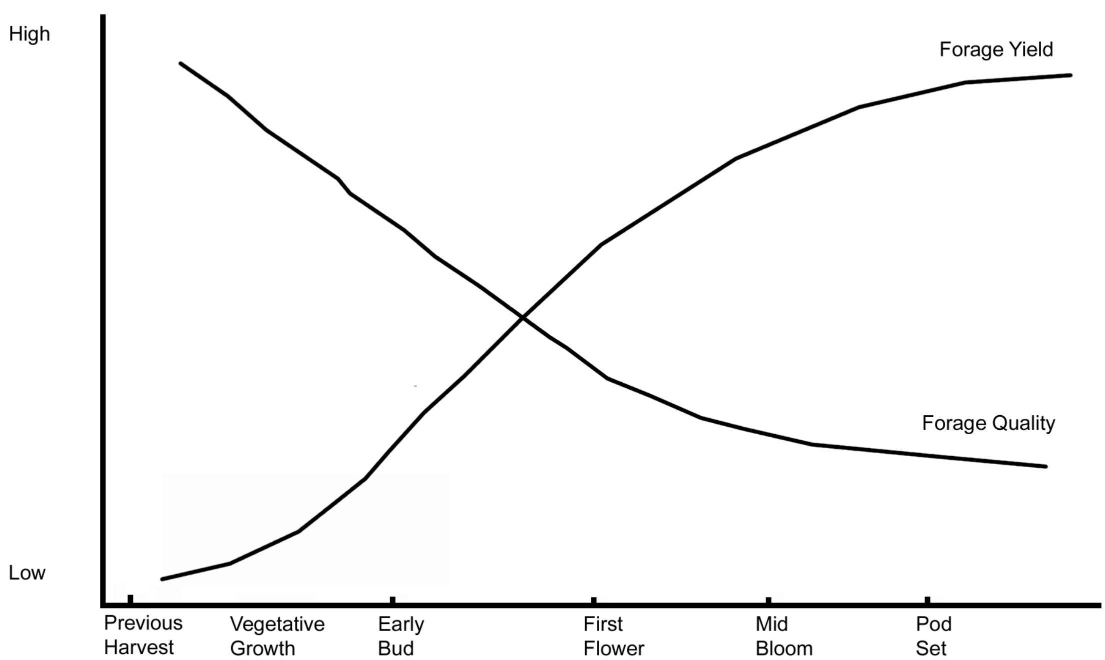

Figure 5-1. Generalized relationships between forage yields and forage quality as affected by stage of maturity

Measures of Forage Quality

Production of high-quality forage depends on several factors, including the art of haymaking and maintenance of weed-free stands. Producers recognize tradeoffs between maximizing forage yield and maximizing forage nutritive value. Figure 5-1 depicts this relationship and indicates how advanced maturity is associated with greater forage yield and lower quality. Picking the optimum harvest time depends on the intended use of the forage.

Alfalfa quality can be characterized in several ways, including color, leaf content, and chemical composition. Describing forage quality by chemical analysis is closely related to animal performance, giving a better indication of relative differences between forages. In addition, chemical analysis provides the least subjective and most uniform system for describing forage quality. Chemical analyses most commonly used as measures of forage quality are neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein (CP), and mineral concentration. Calculated variables such as digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV), and net energy for lactation (NE_L, Mcal/lb.) also are useful measures used by hay marketers and nutritionists to describe forage quality and predict utilization.

NDF is a measure of cell wall or total fiber and increases with advancing forage maturity (see Table 5-2). As NDF increases, voluntary intake of forage by livestock decreases. Estimates of voluntary dry matter intake, as a percent of body weight, can be determined from NDF using the following equation.

Equation:

DMI = 120 ÷ %NDF, dry matter basis

Example:

If NDF = 40%, then
% DMI = 120 ÷ 40
= 3.00% of body weight.

The NDF concentration of alfalfa can be kept low by harvesting at an early stage of maturity and reducing leaf loss during harvesting.

Acid detergent fiber is the portion of the total fiber that is relatively indigestible and increases with advancing forage maturity. As ADF increases, DDM and energy content of forage declines. Estimates of digestibility and energy content can be determined from ADF using the following equations.

Equation:

DDM = 88.9 - (0.779 x %ADF, dry matter basis)

Example:

If ADF = 30%, then % DDM
= 88.9 - (0.779 X 30)
= 88.9 - 23.4 = 65.5%

Equation:

= 1.044 - (0.0119 x %ADF)

Example:

NE_L (Mcal/lb.)
= 1.044 - (0.0119 x 30)
= 1.044 - 0.476
= 0.687 Mcal/lb.

As with NDF, ADF concentration of alfalfa can be reduced by harvesting at an early stage of maturity and by reducing leaf loss during harvesting.

The RFV concept incorporates quality factors calculated from ADF and NDF into a useful index for comparing legume and legume-grass mixtures (see example below). The higher the RFV, the higher the quality and production potential of the forage.

Equation:

RFV = %DDM x %DMI x 0.775

Example:

RFV = 65.5 x 3.00 x 0.775 = 152

For additional information concerning forage quality testing, refer to OSU Extension Facts F-2117.

Forage Quality and Livestock Production

The nutrient requirements of livestock depend on numerous factors (e.g., age, body size, reproductive status, level of milk production, etc.). Because of this, certain qualities of alfalfa are best suited for specific classes of animals (Figure 5-2).

Calves from 1-3 months of age benefit from eating high-quality forage. Alfalfa provided to these animals should be greater than 18 percent crude protein and less than 42 percent NDF. Alfalfa for calves can be preserved either as hay or low-moisture silage (less than 55 percent moisture). High-moisture silage should be avoided because the high moisture content may limit intake and protein quality.

Feeding 3-12 month-old heifers alfalfa that contains 16-18 percent CP and 42-46 percent NDF will generally provide optimal growth with minimum concentrate supplementation. Alfalfa containing 14-16 percent CP and 45-48 percent NDF will meet most of the nutritional needs of heifers 12-18 months old and lactating beef cows.

Heifers 18-24 months old and dry cows are able to utilize alfalfa of lower quality than other classes of livestock. Forage that is 12-14 percent CP and 48-52 percent NDF is adequate for these groups. However, because of its high calcium and potassium content, feeding large quantities of alfalfa hay to adult cows near the end of gestation may lead to metabolic problems at calving. For these animals, the amount of alfalfa offered should be limited to less than 12 pounds per head per day.

No other farm animal reflects differences in the quality of forage as does the lactating dairy cow. High-producing dairy cattle need the highest quality forage, while dry beef cattle can use more mature forage with lower protein content and fiber digestibility. Lowering the quality of alfalfa fed to high-producing dairy cows can dramatically reduce milk production, especially in early lactation. Cows cannot physically consume enough digestible dry matter, even from high-quality alfalfa hay, to produce at maximum inherited capacity. Some level of concentrate (grain and protein supplement) is needed with any quality of forage offered to high-producing dairy cows to obtain maximum milk production. However, the higher the quality of forage consumed by the dairy cow, the lower the amount of concentrate needed to achieve higher levels of milk production and the less likely digestive upset or metabolic disorders will occur.

A good illustration of the importance of high-quality forage for milk production comes

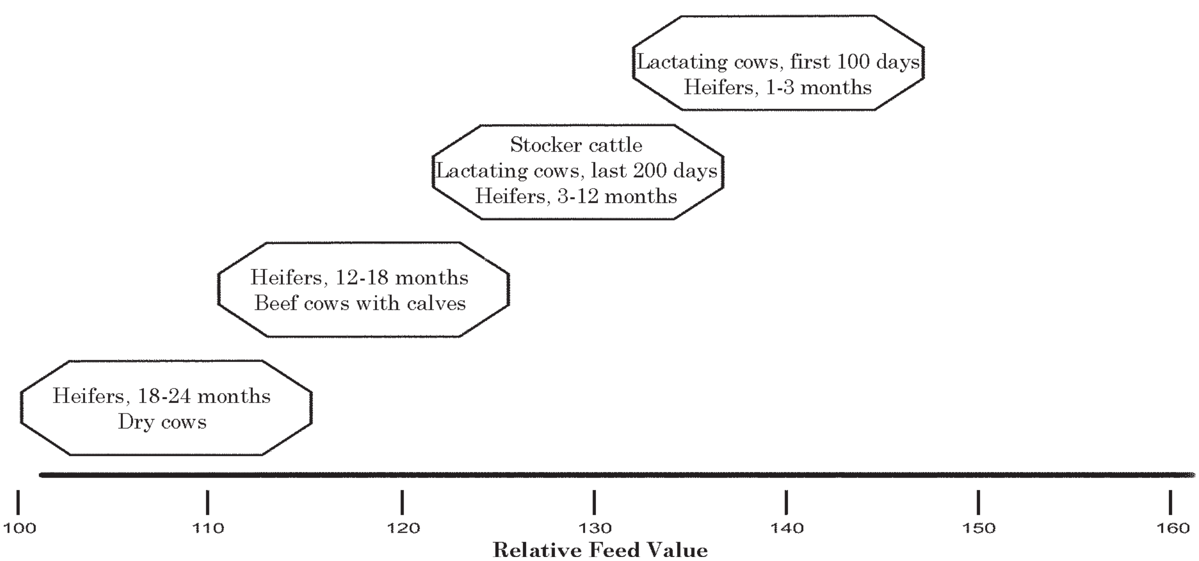

Figure 5-2. Matching relative feed values to animal needs

from a study conducted at the University of Wisconsin that compared alfalfa hay harvested at four stages of maturity fed to high-producing dairy cows (Table 5-1). Levels of concentrate fed were also varied to evaluate its effect on milk production at similar as well as different quality levels of alfalfa hay. In this study, the highest level of milk production was obtained on pre-bloom alfalfa hay at all levels of concentrate feeding. The highest output of milk and apparent peak in profitability occurred at the 54 percent level of concentrate feeding. The main point of this study is the impact forage quality has on milk production. It is also apparent that feeding higher levels of concentrate cannot substitute for lower forage quality. Cows fed pre-bloom alfalfa supplemented with 20 percent concentrate produced more milk than those fed full-bloom hay with 71 percent concentrate.

In general, high-producing dairy cows should be fed alfalfa hay with a quality analysis of at least 20 percent CP, less than 30 percent ADF, and less than 40 percent NDF (the "20-30-40" rule). Lactating cows, during the first 100 days after calving, have high and rapidly increasing nutrient requirements. Alfalfa containing 20-24 percent CP and 36-38 percent NDF is best suited for these animals. Alfalfa lower in CP and higher in NDF will require the feeding of additional amounts of concentrates to achieve a given level of milk production. Further, alfalfa with lower NDF concentrations may not provide enough fiber to maintain proper rumen function. Lactating cows during the last 200 days of lactation have reduced energy and protein demands as milk production declines. Therefore, lower quality forage can be fed after the first 100 days of lactation.

Can alfalfa quality be too high? If alfalfa is harvested too early, it will have low ADF content, high NDF digestibility, and high crude protein content. Although the energy content will be relatively high, it is still much lower than the energy content of corn grain. Diets containing very high-quality alfalfa with low NDF content must contain very high forage levels to meet the cow's fiber requirement. This reduces the energy density of the diet because there is little room left for grain. Attempts to increase energy density by adding grain without regard to fiber requirements may result in metabolic disorders.

Furthermore, protein content of the diet will be excessive because of the high level of forage with a very high protein content. Excess protein is not only wasteful but also costs the cow energy to excrete, may reduce reproductive performance, and contaminates the environment. In addition, forage yields will be lower, and harvesting early may decrease the life span of the alfalfa stand. Rarely do livestock and dairy producers need alfalfa hay with greater than 200 RFV.

Table 5-1. Milk yield as influenced by changes in alfalfa maturity and concentrate feeding level

Concentrate in Ration	Alfalfa Maturity			
	Pre-Bloom	**Early-Bloom**	**Mid-Bloom**	**Full-Bloom**
% of DM	lb. of milk daily			
20	80	68	57	52
37	83	69	62	55
54	87	77	66	65
71	86	77	65	70

Adapted from J. R. Kawas, University of Wisconsin, Madison (1983).

Managing for Quality and Yield

The traditional response for many years to the question regarding when to cut alfalfa was, "Cut at 10 percent bloom for the best combination of yield, quality, and stand persistence." However, there is no single best cutting interval for alfalfa.

The best time to harvest will vary depending on projected use of the hay. If hay will be sold as high-quality forage (for dairy cattle), alfalfa should be cut at bud stage or earlier (23-day cycle or less). If alfalfa is being used as feed for a cow-calf operation where high quality is not as critical, it should be cut at 25-50 percent bloom (35-42 day cycle) to maximize yield and profitability. Figure 5-3 at the end of this chapter illustrates different harvesting cycle lengths.

Producers must decide what intervals are most appropriate for their operations and markets. For example, alfalfa cut when less mature (bud stage) may yield 20-30 percent less forage than mid-bloom hay (Figure 5-1); however, it will have much higher protein content and relative feed value than that cut at mid-bloom (Table 5-2).

If higher quality alfalfa can be sold for $15-$20 per ton more compared with lower quality forage, revenues may be greater with early cutting. If there is little or no price advantage for high quality, later cutting and fewer harvests per year will normally be more economical.

For growers who plan to consistently cut their alfalfa at bud stage compared with bloom stage, the following considerations are important. Assuming the first harvest is taken in late April or early May and that soil moisture is not limiting, a total of six harvests are possible on a 28-day cutting cycle.

Table 5-2. Market hay grades for legumes, legume-grass mixtures, and grasses

Grade	Species and Stage	Description*				
		% CP	% ADF	% NDF	% DDM	RFV
Prime	Legume, pre-bloom	>19	<31	<40	>65	>151
1	Legume, early bloom, 20% grass, vegetative	17-19	31-35	40-46	62-65	125-151
2	Legume, mid-bloom, 30% grass, early-head	14-16	36-40	47-53	58-61	101-124
3	Legume, full bloom, 40% grass, headed	11-13	41-42	54-60	56-57	86-100
4	Legume, full bloom, 50% grass, headed	8-10	43-45	61-65	53-55	77-85
Fair	Grass-headed or rain-damaged	<8	>45	>65	<53	<77

*CP = Crude Protein; ADF = Acid Detergent Fiber; NDF = Neutral Detergent Fiber; DDM = Digestible Dry Matter; RFV = Relative Feed Value. From the American Forage and Grassland Council, Hay Marketing Task Force.

The last harvest would be taken mid- September (see Figure 5-3). This cutting schedule would compare with 4-5 harvests taken on a 35-42 day interval. Although annual yields may not differ greatly between the cutting schedules, added harvest costs of $22-$44 per acre would be incurred with the 28-30 day interval. A higher price must be obtained for the forage cut at bud stage to offset these costs.

Hay vs. Silage

No clear advantage in animal performance has been demonstrated for alfalfa conserved either as hay or silage, although there is an indication that silage supports higher milk production and is more efficiently utilized by dairy cattle. Again, quality is the most important factor determining milk production potential from forage. Field losses are less when alfalfa is harvested at a higher moisture contents; consequently, silage will have lower field losses than hay. Within each

```
APRIL   |   MAY     |   JUNE    |   JULY    |   AUG.    |   SEPT.   |   OCT.

  15       1       15      1      15     1      15     1      15     1      15     1
  | |     | |     | |     | |    | |   | |    | |   | |    | |   | |    | |    | |

       |               |             |             |            |           |
      4/28            5/26          6/23                       7/21        8/18       9/15
   First Cut     Second Cut    Third Cut   Fourth Cut    Fifth Cut   Sixth Cut

28-day schedule = 6 cuts
```

```
APRIL   |   MAY     |   JUNE    |   JULY    |   AUG.    |   SEPT.   |   OCT.

  15       1       15      1      15      1      15     1      15     1      15     1
  | |     | |     | |     | |     | |   | |     | |   | |     | |   | |    | |   | |

           |               |                 |                |                |
          5/1             6/5                              7/10            8/14          9/18
     First Cut      Second Cut      Third Cut       Fourth Cut      Fifth Cut

35-day schedule = 5 cuts
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APRIL   |   MAY     |   JUNE    |   JULY    |   AUG.    |   SEPT.   |   OCT.

  15       1      15       1      15     1      15     1      15     1      15     1
  | |     | |     | |     | |     | |   | |    | |   | |     | |   | |    | |   | |

              |                                   |               |                   |
             5/5                 6/16            7/28                9/8
        First Cut           Second Cut     Third Cut         Fourth Cut

42-day schedule = 4 cuts
```

Figure 5-3. Haymaking time lines; examples of 28-, 35-, and 42-day harvest schedules category (e.g., 13 vs. 18 percent moisture hay or 45 vs. 60 percent moisture silage) losses will be greater with higher-moisture forage unless more expensive storage structures are used (oxygen-limiting vs. bunker silos).

The decision to harvest and store alfalfa as a high-moisture crop is primarily one of risk management. Most alfalfa produced in the western U.S. is baled because of good drying conditions and ease of transport. However, in the northern U.S., alfalfa typically has been ensiled because of the shorter drying time needed for silage versus hay, thus reducing the possibility of the crop being damaged by rain.

Dates shown in these haymaking time lines are assumed to be for central Oklahoma. With normal growing conditions, producers in southern parts of the state should begin about five days earlier, and those in the north should delay first harvest about five days. Temperatures during early April affect ideal timing of first harvest. Dry periods during July and August frequently prolong harvest intervals during that period. As an alternative, producers with livestock should consider utilizing late summer forage by grazing. (See Chapter 7, "Grazing Alfalfa.")

Chapter 6
Haying: Handling and Storage

Alfalfa production budgets show that equipment costs (purchase, operating, and maintenance) account for about 40 percent of the cost of hay production. Many aspects of haying have to do with equipment. AGMACH$ is a software that addresses many of the details and cost tradeoffs for various types of equipment.

Alfalfa yield and quality are highest at the moment of harvest. In other words, yield of a particular cutting cannot increase after it is harvested. In fact, respiration continues for sometime after harvest, thereby decreasing total dry matter. Nothing can be done to improve alfalfa quality after it is cut; however, many factors begin at the moment of harvest to reduce forage nutritive value. By not harvesting alfalfa effectively or allowing the hay to "weather," forage quality is reduced and marketability is impaired significantly.

Alfalfa can be harvested using several different methods for diverse purposes. It can be harvested and utilized fresh as green manure, green chopping, or grazing. In these cases, moisture concentration usually ranges from over 80 percent to 65 percent, and dry matter losses are insignificant. When harvested as silage alfalfa, haylage, or baleage, moisture ranges from 60 percent to 50 percent, and quality can be maintained with little harvest loss. In Oklahoma, alfalfa is usually harvested and stored as baled hay with moisture concentrations less than about 20 percent. Dry matter losses in harvesting, handling, and storing dry alfalfa can range from as little as 10 percent to over 30 percent. Quality losses often accompany dry matter losses.

The rest of this section is devoted to methods of harvesting alfalfa as hay with an emphasis on minimizing yield and quality losses. A critical factor to consider is that harvesting, handling, and storage can represent over 40 percent of the total cost of alfalfa hay production. These inputs can mean the difference between profit and financial failure due to the magnitude of investments. Profitable production and marketing high-quality forage requires proper harvesting, handling, and storage. Buyers are often willing to pay a premium for high-quality hay. Based on several years of Oklahoma HAYMARKET data, buyers paid an average of over $2.40 per ton more for each percentage point increase in protein.

Cutting

Cutting and conditioning are the first of several critical steps to ensure high-value hay. Hay quality is directly related to leaf retention because leaves contain a higher proportion of crude protein and energy than stems. A growing alfalfa plant contains approximately 80 percent water. When the plant is cut, it continues to respire or "breathe" until water content is reduced to about 40 percent. Below 40 percent, leaves dry at a much faster rate than stems because leaves are thin and have a relatively large ratio of surface area to mass in comparison to stems. Because of the cell structure and surface wax layer of stems, drying occurs slowly. By the time stems reach proper moisture content for baling, leaves may be too dry and may shatter easily.

The relatively simple subject of cutting alfalfa includes the consideration of many different pieces of equipment. Each piece of harvesting equipment has certain advantages and certain disadvantages. Before arbitrarily purchasing harvesting equipment, producers should consider sickle bar mower, mower-conditioner, rotary disk mower, disk mower, conditioner, pull-type windrower, self-propelled windrower, etc.

Raking

Raking is used to enhance uniform drying. The most common type of rake rolls and fluffs the windrow, bringing the bottom layer to the top. The rolling action exposes more of the stems while protecting the leafy portion of the plant. Hay should be raked when the moisture content is above 30 percent to minimize leaf shatter. Raking during the early morning or late evening after the leaves absorb moisture from the air can further reduce leaf loss. Dry matter losses can range as high as 15 percent if alfalfa is raked when it is too dry. Some raking options include side delivery rake, twin side delivery rake, wheel rake, twin wheel rake, windrow inverter, etc. Each tool has certain strong points.

Baling

When to bale

To avoid severe storage losses from excessive heating and molding, alfalfa should be baled at no higher than about 20 percent moisture. Alfalfa can be baled and stored successfully, however, at higher moisture contents by using preservatives. Depending on the type of preservative, hay can be baled at moisture contents as high as 35 percent. Baling at higher moisture content reduces the time hay is exposed to weather and decreases dry matter loss because there is less leaf shatter. Minimizing leaf loss can also mean a higher crude protein content.

Optimum moisture content for baling depends on bale size. For small rectangular bales, the moisture content should be no higher than about 20 percent without preservatives. The upper limit for large bales, both rectangular and round, is about 16 percent to avoid taking special precautions to prevent excessive heating. If large round bales are stored outside and unprotected, moisture content at baling can be increased to about 20 percent.

Without the aid of an electronic moisture meter, experienced hay producers often rely on two rule-of-thumb methods for determining when alfalfa hay is dry enough to bale. One method is to take a handful of hay from the underside of the windrow and twist it. If there is no free moisture present and the stems are brittle, the hay should be in good condition for baling. If the hay is very dry and brittle, it is probably too dry to bale. When the stems appear too dry, allow the leaves to absorb moisture from the air during late evening or early morning before baling, a process often called “casing-up.” Scraping the epidermis or outside layer of the stem is another method used to determine when to bale. If the stem epidermis can be peeled off, the hay is too wet. If the epidermis doesn’t peel away, the hay is dry enough to bale.

An electronic forage moisture meter can be a useful tool for determining proper moisture content at baling. These may be used in the windrow but are more reliable when the hay is baled. Probe from the end of rectangular bales and through the diameter of round bales. Take at least five probes of each bale and average the readings. Probe several bales to account for field variations. If the readings vary by more than three percentage points, take several more probes and recalculate the average.

There are many factors that affect the accuracy of a moisture meter. Two factors are bale density and the use of chemical conditioners. Probing bales that are very “tight” may yield readings over two points higher than the actual moisture content. Some preservatives, such as propionic acid, can increase readings as much as four percentage points. If preservatives are used and the instruction manual for the meter does not provide information on the effects of chemicals on performance, contact the manufacturer of the meter for additional information.

Bale Size

___**Small rectangular bales** were the most common bale type for alfalfa in Oklahoma for many years. The most popular size for these “square” bales was 14 x 18 x 36 inches long, weighing between 70 and 80 pounds, depending on moisture content. Normal baling rates range from 5-10 tons per hour. In good baling conditions (heavy windrows and high moisture content), leaf loss at the pickup and in the bale chamber should be less than four percent. Bale chamber losses may exceed five percent with overly dry alfalfa.

Large rectangular bales are the preferred bale type for many dairies. Bale size ranges from about 2 x 2 x 8 feet long (mid-size), weighing about 750 pounds, to 4 x 4 x 8 feet long (large), weighing about 2000 pounds. Normal baling rates range from 15 to over 25 tons per hour. In some cases, smoothness of the field dictates ground speed. Dry matter losses during baling are comparable to small rectangular bales. A major disadvantage of large square bales is baler cost, which can be more than three times the cost for small square or large round balers.

Large round bales were introduced in to Oklahoma in the early 1970s. The popularity of these bales can be attributed to low labor demand. Common bale sizes range from four feet diameter by four feet long, weighing about 600 pounds, to six feet diameter by six feet long, weighing about 2000 pounds. Normal baling rates range from 8-16 tons per hour. Most large, round balers are comparable in price to small rectangular balers. In overly dry hay, alfalfa leaf loss can be as high as 10 percent at the pickup and 25 percent in the baling chamber. Under optimum conditions, total losses can be held to about five percent. Using high feed rates that reduce the time a bale is being formed can minimize bale chamber losses.

Mechanical Conditioning

The most common method of enhancing stem drying is mechanical conditioning. Conditioners use a set of intermeshing, counter-rotating rollers that crush, bend, or break stems, allowing moisture to escape easily. If the stem dries faster, the hay can be baled sooner, which reduces the time hay is exposed to the weather. Conditioners also result in reduced leaf shatter during raking and baling because the leaves tend to dry at about the same rate as stems. Proper roller clearance adjustment is important. Roller spacings used for the thick stems at first cut are often inadequate for the fine stems in subsequent cuttings. It should be noted that mechanical conditioning is <u>not</u> recommended if blister beetles are present. (See Chapter 2, "Insect Management," for details.)

Chemical Conditioning

Hay additives can reduce field curing time and decrease losses during baling. However, before investing in equipment and chemicals, be sure to consider the additional time, labor, and cost that will be required. Chemicals should never be used as a substitute for good management practices. Chemicals available to help condition hay include two major groups — drying agents and inhibitors. They work in different ways.

Drying agents normally contain potassium carbonate or sodium carbonate, which are alkaline salts. These chemicals change the water-transmitting properties of the surface wax layer, allowing moisture to escape readily. Studies show that total drying time can be cut by as much as 24 hours, with the average being about 12 hours. In Oklahoma, the greatest potential for profitable use of drying agents is during periods of poor drying conditions consisting of low temperature and high humidity, common during the first cutting. However, some studies show the difference in drying times between treated and untreated alfalfa for the first cutting may be small because of the high volume of forage and the possibility of wet ground, which retards drying. When using chemical conditioning, the shields on mower-conditioners should be adjusted to lay the hay on the ground in a thin layer covering the full swath width. Drying agents are more effective when the hay is dried in a thin mat.

Depending on the type of drying agent and recommended application rate, chemical conditioning can cost from $3 to over $8 per ton of treated hay. In addition, the cost for applicator parts and equipment can range from $700 to over $1,200. The additional labor demand can also be a factor. Mixing and handling water and chemicals can increase total mowing time as much as 20 percent.

Inhibitors help avoid severe storage losses from excessive heating and molding when alfalfa is baled at moisture contents higher than 20 percent. Depending on the type of preservative, hay can be baled with moisture content as high as 35 percent. Baling at higher moisture content reduces the time hay is exposed to weather and decreases dry matter loss because there is less leaf shatter. Minimizing leaf loss can also mean a higher crude protein content. The three most commonly used inhibitors are organic acids, ammonia, and inoculants.

Organic acids, such as propionic acid, can be used for treating hay up to about 35 percent moisture content. It is sprayed onto the hay as it enters the baler. Uniform coverage is very important. Organic acids inhibit mold growth and enhance bacterial growth. One of the major drawbacks to using the original acid was the corrosive effect on equipment. Buffered propionic acid is now commonly used to avoid corrosion problems. Another potential problem is odor. The acid vapors can be annoying, especially in poorly ventilated storage. Preserving alfalfa with organic acids can be expensive. Equipment and chemical costs can range from $8 to over $12 per ton.

Ammonia, another mold inhibitor, is usually applied to baled hay after it is placed in storage. Bales with up to 30 percent moisture content are stacked and covered with polyethylene. Anhydrous ammonia is released under the cover at a rate of about two percent of hay weight. The stack is sealed for at least two weeks. Ammonia inhibits both mold growth and bacterial growth. In addition, the nitrogen content of ammonia will result in a small increase in the crude protein content of the hay. Equipment and chemical costs for using anhydrous ammonia as a preservative range from $5 to about $8 per ton of hay.

The major disadvantage of anhydrous ammonia is human and animal safety. For humans, strong concentrations can cause severe burns, blindness, and death. When applied to moist hay, ammonia combines with the moisture in the hay and becomes relatively harmless. However, vapors from treated bales can be irritating, especially in poorly ventilated areas. It has been reported that ammonia-treated forages have caused toxic reactions in animals. Symptoms of the toxicity include hyper-excitability, circling, convulsions, and death. Newborn calves that are nursing from cows fed these forages are also susceptible to the toxicity. It is important that anhydrous ammonia be used with care and applied at the recommended rate. If signs of toxicity occur, the feeding of treated alfalfa should be discontinued.

Inoculants usually consist of bacteria or enzymes that create an environment in the bale that stops growth of hay-rotting bacteria and molds. They are applied to hay as it enters the baler, usually as a dry product. It appears that inoculants can be effective at moisture contents as high as 25 percent. Once in the bale, inoculants work somewhat like preservatives. Inoculants are probably the most economical means of preservation because little is invested and little can be lost. If it saves some hay from molding and prevents a barn from burning, inoculants are worth the money. Equipment and chemical costs can range from as low as $2 to over $5 per ton.

Hay Storage

Most alfalfa hay in square bales (small and large) is placed in covered storage. Commercial hay producers prefer enclosed barns to retain color and minimize storage losses. Under-roof storage with one or more sides open is also popular, especially for round bales. Open sides are usually away from prevailing winds. Hay is stacked tight along open sides and at the top to prevent rain and snow from blowing into the building. Barns and under-roof storage should be located on a well-drained site and as close to feeding areas as possible.

Dry matter losses in enclosed barns are usually less than two percent during the first nine months in storage, while losses in under roof storage can be as high as five percent (Table 6-2). Losses in forage quality, such as crude protein and fiber, are negligible. The major drawback to barns and under-roof buildings is cost. Initial cost of construction can range from about $2 to over $6 per square foot. Building payback time could take over 10 years, depending on the cost of the structure and hay prices.

Because of their shape and ability to shed precipitation, large round bales are often stored outside and unprotected. Research shows, however, that dry matter losses can reach 25 percent, depending on bale quality and storage conditions (Table 6-2). Serious deterioration is usually confined to the outside 4-8 inches of the bale. However, in a five foot-diameter bale, the outer eight inches represent about half of the bale's volume. The depth or thickness of weathering depends on many factors including the amount of rainfall during the storage period, condition of alfalfa when baled, bale shape, and density.

If bales are stored outside and unprotected, there are several guidelines that should be followed to minimize hay loss:

- Storage sites should be well drained, unshaded and open to breezes (to enhance drying after rains).
- Bales should be well shaped and as dense as possible.
- Adjoin bales end-to-end in rows oriented north-south and provide at least 3 feet of space between rows to help maintain dry conditions around the bales.
- Keep grass and weeds mowed between rows.
- Use bales that are unprotected by

Table 6-1. Summary of preservatives, inoculants, and desiccants used in harvesting alfalfa

Drying agents - sprayed on just in front of the swather

- Contain potassium or sodium carbonate, which help break down the outer part of the stem and allow water to escape.
- Require complete coverage of stems for quick drying.
- Work best under good drying conditions.
- Cannot help stems inside a huge windrow during humid weather.
- Fastest drying occurs in swaths that are the same width as the cutter bar.
- May reduce drying time by a day or more.
- May not speed drying time more than a few hours under poor drying conditions.
- Economics vary with drying conditions.

Inhibitors - applied just in front of the baler, *except ammonia**

- Buffered propionic acid is the most popular liquid inhibitor.
- Allow hay to be baled and stored at 20 percent to 30 percent moisture without mold.
- Require high rates of the product with large volumes of water.
- Are costly, and slow the baling operation because of hauling the water.
- May be profitable when baling high-moisture hay when rain is imminent.
- Should be used when there is no time to let hay dry.
- Inoculants are applied to hay as a dry product.
- Consist of bacteria or enzymes that create an environment in the bale that stops growth of hay-rotting bacteria and molds.
- Work somewhat like preservatives once in the bale.
- Probably the most economical means of preservation. Little is invested and little can be lost.

*Anhydrous ammonia should be applied to stack under plastic with much caution.

March 1 because spring rains and warm temperatures can cause substantial losses in dry matter and forage quality.

Covering bales with plastic or tarps is another storage option, especially for round bales. However, dry matter losses can range as high as 10 percent for alfalfa stored up to nine months under a cover on the ground, depending on weather, soil conditions, and bale density. Avoiding ground contact by setting the bales on pallets, racks, fence posts, or railroad ties can save over five percent in dry matter losses.

Cost of hay covers, not including labor, can range from less than $2 to over $7 per ton, depending on the type of cover and the size of stack. Covers often require continual attention for repairing tears and resecuring tie-downs, especially during periods of high winds.

Handling and Transportation

Bale handling and transportation are important factors when choosing bale type. For small square bales, the most common field-handling method consists of a pop-up loader attached to a flat-bed truck. Bales are taken to storage or loaded onto a semi-trailer for shipping. Field loading rate is about 1.5 tons per man-hour. At least two people are needed for loading. Because custom haulers and locally hired laborers became so difficult to employ, alfalfa producers with large acreages have changed to using automatic bale wagon systems. An automatic bale wagon with one operator can replace a three man crew.

High labor requirements and increasing costs of hand hauling have caused some commercial growers to abandon their small square bale operation for large bale package such as large rectangular bales. Large rectangular bales are loaded onto flatbed trucks or semi trailers directly in the field at about 20 tons per man-hour. Commercial haulers prefer large square bales to small square bales because they can drive into a field and be loaded for a cross-country trip in less than an hour.

Transportation can be a major problem with large round bales. Interstate hauling regulations limit load widths to 8.5 feet. In Oklahoma, commercial hay haulers are allowed to transport a load of round bales up to 11 feet in width, during daylight hours only, after securing a special oversize-load permit.

Avoiding Hay Fires

Spring and early summer cuttings often present the greatest risks for hay fires because of the difficulties of drying hay before baling. No matter the time of year, if rain is in the forecast, hay producers are often tempted to bale at a little higher moisture content to avoid weather damage. If hay is baled too wet and packed too tightly into storage, severe heating can occur, causing significant dry matter and quality losses or worse – a hay fire.

Heating results from plant respiration and microbial activity. It can occur in baled hay at moisture contents as low as about 13 percent. Therefore, heating is a natural occurrence with temperatures reaching over 120ºF even in hay baled at safe moisture contents. If excess moisture is present, heat-resistant fungi be-

Table 6-2. Percent dry matter loss of alfalfa hay bales

Storage Method	Storage Period Up to 9 Months	12 to 18 Months
Barn	>2	2 - 5
Under-roof	2 - 5	3 - 10
Under cover	5 - 10	10 - 15
Outside, unprotected	5 - 20	15 - 50

come active, which can drive the temperature to over 150ºF. Above about 170ºF, the microorganisms die, but heat-producing chemical reactions continue to drive temperatures up. Between 450º and 550ºF, spontaneous combustion can occur if the material is exposed to air.

Hay fires can occur over two weeks after the hay is placed into storage. Generally, temperatures below 140°F indicate no particular heating problem. Check the hay daily to see if temperatures continue to rise. Temperature readings between 140º and 170ºF provide no clear indication of pending problems. Check the temperature every few hours to monitor changes. If the temperature is above 180ºF, call the fire department. DO NOT MOVE THE HAY UNTIL THE FIRE DEPARTMENT IS PRESENT. When smoldering hay is exposed to air, it can undergo spontaneous combustion. It is imperative that the fire department be present before you attempt to move any hay with a temperature above 180ºF .

If it is not possible to measure temperature with an instrument, use a long steel rod as a probe. Drive the rod into the inner stack and leave it for at least 15 minutes. If the rod is too hot to handle, the temperature inside the stack is probably above 120ºF and caution is warranted. Never stand on top of a stack you suspect may be heating because smoldering hay can create a cavity or pocket that often cannot be detected from the top of the stack.

Preventing hay fires begins at the time the hay is baled. Optimum moisture content for baling depends on bale size. For small square bales, the moisture content should be no more than about 20 percent without preservatives. During warm, moist air conditions, reduce the moisture content when baling small squares to 18 percent. The upper limit for large packages, including round bales, is about 16 percent to avoid taking special precautions to prevent excessive heating. Round bale moisture content can be increased to about 20 percent if bales are stored outside and unprotected.

Bale density also affects heating. The denser the package, the greater the resistance for heat to move through the hay. For round bales, consider reducing the bale diameter if baling wet hay. If you have a fixed-chamber baler, consider not wrapping the outer layer as tightly as usual to reduce bale density.

If you bale wet hay, it is a good practice to leave round bales outside for at least a week before putting them into barn storage. If you must place bales immediately into the barn, stack bales loosely to allow plenty of air circulation. For large packages, arrange the bales loosely in a single layer for at least two weeks before stacking tightly. Granted, this takes more time and labor, but the risk of a fire is greatly reduced.

Chapter 7
Grazing Alfalfa

Harvesting alfalfa by grazing with livestock can be profitable for experienced producers who utilize critical management practices. Producers who are unfamiliar with managing livestock on lush forages should be extremely careful and attempt grazing only on a small scale. Without proper management, losses of livestock due to bloat can become quite costly. Grazing has been reported to shorten the life of alfalfa stands, compared to harvesting alfalfa for hay; however, if proper management practices are followed, grazing effects on stand life are negligible.

For most alfalfa production situations, grazing during fall and winter has more advantages than disadvantages. Spring grazing, however, is difficult to manage for most producers, and successful summer grazing can be considered intermediate from the standpoint of both positive and negative aspects. Considerations to be taken into account when determining whether to graze alfalfa follow.

Positive Aspects

Some reasons to consider grazing alfalfa include:

In spring, harvesting alfalfa by grazing can reduce weather-related problems associated with normal timing of first harvest (late April and early May). First-cutting hay yields are normally high, resulting in large windrows. The hay is difficult to dry and frequently requires 5-10 days without rain. As a result, most first-cutting hay is damaged by rain before it is dry enough to bale.

Alfalfa grazed in late March or early April is not ready to harvest again before May 15 to 20 under normal conditions. By that time, the frequency of rainfall is likely to be lower, and temperatures are higher; thus, hay dries more rapidly with less chance of rain before baling. Furthermore, the volume of hay is reduced and should be easier to cure.

In spring, producers often need high-quality forage for stocker cattle that were maintained on wheat pasture during winter. Alfalfa can be used for this purpose, and average daily gains may be comparable to those on wheat (frequently from 1.7 to 2.3 pounds per day).

Grazing alfalfa infested with weevils and/or aphids during spring can reduce the habitat available to the insects and results in mortality of large numbers of insects, greatly reducing the need for insecticide application. The highest mortality of alfalfa weevil and aphids results with spring grazing.

In **summer** grazing is especially attractive when hay yields are low during July and August due to dry conditions. Summer grazing also is a good way to utilize thinning stands infested with grasses and other weeds. Normally, forage nutritive value of these weeds is good, and grass in alfalfa reduces the chances of bloat.

In **late fall and winter**, grazing is the most effective and economical means of utilizing late-season forage. Late fall and winter grazing is a good means of reducing alfalfa weevil infestations by effectively reducing sites for weevils to lay eggs. Additionally, livestock will consume existing eggs in alfalfa stems.

Negative Aspects

Grazing alfalfa during active growth is a challenge, and there are concerns associated with this practice. Therefore, few producers in Oklahoma routinely graze actively growing alfalfa. Some of the major concerns include:

Bloat: Fear of losing animals to bloat is the most frequently cited reason for not grazing alfalfa. Lush alfalfa growth in early spring is the most likely period for bloat to occur. All alfalfa varieties can cause bloat, including those called “grazing alfalfa.” Careful

Table 7-1. Practices to lessen the occurrence of bloat when grazing alfalfa

- Do **not** put hungry cattle on lush alfalfa.
- Fill animals with dry grass or hay before grazing alfalfa.
- Provide a bloat preventative (such as poloxalene) for several days before and after the start of grazing alfalfa.
- Closely watch cattle several times a day at first.
- Give cattle a choice of eating dry feed or fairly mature grass when grazing alfalfa.
- Some producers use a “chronic bloater” in the herd as an indicator.
- Remove all animals from the alfalfa at the first sign of bloat and watch closely.
- Do **not** turn cattle onto alfalfa wet with dew. Wait until it dries completely.
- Do **not** begin early in the morning. Fewer problems occur when starting in the afternoon.
- Pay close attention to weather forecasts and remove animals before weather changes.
- Do **not** graze alfalfa that is lightly frosted.

management of animals can minimize bloat problems. Bloat is less prevalent during the summer; nevertheless, precautions should be taken to guard against it. Accepted practices to lessen the occurrence of bloat are listed in Table 7-1.

Inconsistent animal performance: Weight gain depends on many factors including animal type, previous nutrition, forage availability and quality, and environmental stress (heat, cold, mud). Management of livestock and the grazing system has a tremendous impact on many of these factors. For example, animals forced to consume low-quality, mature alfalfa frequently gain less than one pound per day. Intensive management and favorable weather conditions are required to maintain maximum animal performance.

Stand loss: Removing animals when the soil is saturated to the point that animals leave deep tracks can minimize stand loss problems (another reason for not grazing alfalfa). Rotational stocking or mob grazing (high stocking density for a day or two) to remove forage quickly normally results in no stand loss problems as long as adequate rest periods between harvests are provided.

Grass and weed infestation: Grazing alfalfa in early April can increase the amount of cool-season grass in the second alfalfa harvest. Vigorous alfalfa often smothers grasses during April. However, removing alfalfa allows light to reach the grasses that are then able to compete with alfalfa and produce seed. If weed-free hay is the target for second harvest, then weeds should be controlled with a selective herbicide before grazing.

Grazing Practices during the Growing Season

There is no single acceptable practice for grazing alfalfa. Both continuous and rotational stocking is possible and can be successful if managed properly.

To reduce the chances of damaging stands and to maintain stocker gains between 1.5-2 pounds per day, some type of controlled or rotational stocking should be practiced. There is no set rule on the number and size of paddocks; however, paddocks should be small enough for animals to complete grazing in less than a week. Ideally, allow 4-5 weeks for recovery before another round of rotational grazing begins. A good program would be to divide the field into eight paddocks and graze each area four days. To prevent damage to the stand, cattle should be removed when fields become muddy.

Rotational stocking (grazing less than five days followed by regrowth for at least three weeks) will result in high forage production and animal gains. In general, good hay-type varieties respond in the same way to rotational stocking as to cutting for hay.

Rotational stocking can minimize the ill effects associated with thinning alfalfa stands because of grazing. Animals should not be left on any particular part of the field longer than one week. If animals remain on the field longer, much of the available forage is lost by trampling, and new regrowth will be eaten. Rotational stocking should alleviate both of these problems. The best combination of days of grazing and regrowth changes during the growing season because alfalfa grows at different rates. It matures most rapidly when temperatures are high (90ºF and higher) and there is adequate moisture.

Continuous stocking of hay-type alfalfa (and probably grazing types) should be managed so alfalfa is not grazed shorter than 6 inches. This means stocking rates are adjusted several times during the growing season by removing and introducing animals as dictated by alfalfa growth rate.

Research at the Grazinglands Research Laboratory at El Reno, OK, has shown continuous stocking is a good method for grazing stockers, resulting in gains in exceeding two pounds per day using a well-adapted hay-type alfalfa variety. However, many producers find this system difficult because of the need to divide the herd and adjust stocking rates with each change in growing conditions.

Economics of Grazing during the Growing Season

A strong argument for grazing alfalfa is the reduced cost of harvesting. Stocker gains of 1.5-2 pounds per day are attainable. Alfalfa yields of 0.75 tons per acre (grazable) can be assumed in early to mid-April. Assuming stockers consume 15 pounds per head per day, 100 stocker-days per acre are present in typical alfalfa stands. Allowing one week to consume available forage, approximately 14 head per acre would be used, gaining 14 pounds per acre on average. At $0.30 per pound of gain, almost $59 per acre could be earned during a one-week grazing period. Cost of grazing would include fencing, labor, poloxalene, and dry hay for bloat control.

Economic return is also a reason for interest in summer grazing. Cutting, raking, and baling cost approximately $21 per acre per cutting. If weed-free hay sells for $80 per ton and grazable summer yields are 0.5 tons per acre, only $14 per acre would remain after harvest and hauling costs. With grazing as an alternative, assuming one pound of gain for each ten pounds of forage, 100 pounds of beef gain could be achieved. One hundred pounds of gain would be worth $30 per acre at current rental rates ($0.30 per pound gain). If a producer owns the cattle, a higher return could be achieved.

In late summer, instead of making hay, a better option may be to graze droughty alfalfa. Grazing is the least expensive way to harvest alfalfa. When alfalfa is droughty in the summer, bloat problems are easily controlled. During late summer, when alfalfa stops growing, mob grazing can be a very good way to harvest.

Stockers can gain between 1.5-2 pounds per day on this type of forage. Considering 600 pounds per acre of alfalfa are present and stockers consuming 15 pounds per day, there are about 40 stocker-days of forage per acre. Stocking at four stockers per acre, the field can be cleaned in 10 days. If the cattle gained 1.76 pounds per day worth $0.30 per pound of gain, the forage is worth about $21 per acre, about the same as the value of hay, without harvesting equipment costs. As with spring grazing, cost of grazing includes fencing, poloxalene, and labor.

Late Fall and Winter Grazing

Mob grazing alfalfa after the first killing frost (20°F) in November or December is likely to be a better option than trying to make hay. Making hay during this time is difficult because of poor drying conditions—i.e., low temperature, high relative humidity, and reduced solar radiation.

Another consideration is the value of the hay. The value of hay would be about $40 per acre (gross), assuming 0.5 tons per acre (grazable) at $80 per ton. When harvesting cost is approximately $21 per acre, only $19 per acre remains to cover costs of hauling and storage. This optimistically assumes the hay is baled before it is damaged by precipitation. Grazing would cost much less than haying, assuming no stocker loss due to bloat. Using a grazing value of $60 per ton, the 0.5 tons per acre yield would be valued at $30 per acre. Expenses of grazing include bloat prevention, fencing, and labor.

Grazing after frost also helps control insects. During grazing, sites for alfalfa weevil eggs are removed and eggs in stems are consumed, reducing the number of eggs available for hatching the following spring. Grazing on dry fields after a hard freeze will also result in some control of broadleaf weeds. Further, the hoof action of the livestock will cause uprooting of small weeds. (See Chapter 2, "Insect Management - Alfalfa Weevil" for details.)

Pasturing Dairy Cattle

Recently, some dairy producers have taken another look at grazing for their lactating herd as a way to make more effective use of their land and reduce operating costs. The key to success in grazing alfalfa with dairy cattle is to manage the fields in a grazing system with adequate periods of rest to allow for proper regrowth. The following are suggestions producers should follow to reduce potential problems and provide effective grazing.

To reduce the potential of bloat during spring grazing, cows should be fed before being allowed access to pasture. An additional precaution may be to limit access to the pasture. Over a period of one to two weeks, cows may be allowed access for increasing intervals until animals are on pasture continuously. Once adapted, bloat usually does not occur unless cows are forced to graze pastures too closely and are hungry when moved to the next paddock.

Move cows to new paddocks frequently in order to ensure high-quality forage is available daily. Low-producing cows, heifers, and dry cows may be allowed to graze after the high-producing cows to clean up pastures and make use of the lower-quality forage.

Grazing may provide 40 to 50 percent of total dry matter intake. The remainder of intake can be used to balance the ration.

High producing cows may need some source of rumen-undegradable protein (e.g., blood meal, fishmeal, etc.) to meet protein and amino acid requirements for high production.

Feeding high-starch feeds such as corn will help "capture" the soluble protein portion of alfalfa and increase rumen microbial protein production.

Feeds such as soybean hulls, whole cottonseed, wheat midds, or corn gluten feed may also be incorporated into the grain mix to provide appropriate levels of highly digestible carbohydrate while providing a source of fiber. Additionally, some hay also may need to be fed to maintain fiber levels in the ration and to prevent digestive upsets and milkfat depression.

Pasture based dairy operations can achieve excellent production levels while controlling input costs. However, close attention to detail, proper supplementation, and use of rotational stocking are needed in order to realize maximum benefit from an alfalfa grazing system.

Chapter 8
Marketing

Marketing, including marketing alfalfa hay, involves being customer oriented. Marketing means listening to buyers and understanding their wants and needs. Customers for alfalfa may be beef cattle producers, cattle feedlots, milk producers, horse raisers, or sheep producers. Each set of customers has different needs. Thus, effective marketing begins before production and involves selecting target markets, planning production practices to produce alfalfa for each target market, and considering the timing of marketing. This section is a summary of marketing and price information developed in several studies during the last decade.

Quality

Alfalfa quality is essentially the feed value of alfalfa. Different animals and feed rations can utilize different levels of feed value or quality attributes in alfalfa. The quality of alfalfa affects the target market for the hay produced and the price received for alfalfa marketed. Quality also affects production costs and practices. Targeting higher-quality alfalfa may reduce the quantity of alfalfa hay produced.

Dairy producers usually want alfalfa with a high relative feed value, meaning leafy alfalfa harvested in the bud stage. Horse producers want soft, green, leafy alfalfa free of blister beetles. Beef cattle and sheep producers may be more willing to use lower-quality hay.

In response to a survey, dairy producers rated crude protein (CP) as the most important factor when buying hay. The lowest acceptable protein content, on average, was 19.9 percent for high-producing cows and 16.2 percent for dry cows.

The second most important quality measure was total digestible nutrients (TDN). On average, the lowest acceptable level of TDN was 64 percent for high-producing cows and 57 percent for dry cows.

Growers indicate that increasingly, buyers want to know the relative feed value (RFV) of alfalfa for sale. Yet RFV was the third most important objective measure of alfalfa quality, behind CP and TDN. The lowest acceptable RFV content, on average, was 157 for high-producing cows and 135 for dry cows.

Research shows that buyers pay more for higher-quality alfalfa. Table 8-1 illustrates how much HAYMARKET prices changed in 1992-93 with a one-unit change for each quality measure. Note each relationship is independent of the others and not additive. The price premium for a one percent increase in crude protein (CP) averaged $1.34 per ton for the production years 1983-87. The premium for an individual year ranged from a low of $0.33 per ton (not statistically significant) to a high of $3.25 per ton. These show a clear positive relationship between alfalfa quality and prices paid or received, even with the variation caused by other alfalfa attributes.

Weeds Affect Hay Value

Dairy producers are also interested in knowing the amount of broadleaf and grassy weeds in alfalfa. Buyers rated the amount of weeds among the most important types of information about the alfalfa they purchase. Alfalfa hay with less than five percent weeds was chosen as the basis for comparison. Buyers significantly discounted alfalfa hay with large amounts of weeds. Hay sold with larger amounts of weeds was discounted $8.17 to $25.11 per ton. Clearly, buyers are looking for alfalfa hay that is nearly weed-free, and growers have a price incentive to keep their alfalfa free of weeds.

In addition, growers have a cost incentive related to controlling weeds and thereby prolonging stand life. Proper weed control (see "Weed Management in Alfalfa" in Chapter 2) significantly affects alfalfa yields as well as quality. In addition, as noted in Chapter 11, stand life is extremely important to profitability of the alfalfa enterprise. As stands begin to thin, proper weed control becomes a key factor in extending profitable returns.

Bale Type and Size

The harvesting package affects the cost of transporting and handling alfalfa, thus helping to identify your target market. Chapter 6, "Hay Handling and Storage," discusses the most common harvesting packages. Many dairy producers want alfalfa in large square or small rectangular bales but not round bales. Horse owners prefer small rectangular bales to large square or round bales. Beef cattle and sheep producers may prefer round bales or small rectangular bales.

For research on the price differences of bale sizes per types, small rectangular bales were used as the basis for comparison. Large square bales were discounted $7.51-$10.17 per ton compared with alfalfa hay sold in small rectangular bales. Round bales were discounted $16.43-$26.83 per ton compared with small rectangular bales. The discount for round bales was not surprising, but the discount for large square bales was unexpected. Some growers harvest alfalfa in round bales when they perceive that alfalfa quality does not merit using more expensive packages. If buyers are aware of this practice, it makes it more difficult for growers with high-quality alfalfa in round bales to market their alfalfa at prices commensurate with its quality.

As noted previously, the market values bale sizes differently. As market conditions change, the value changes. Also, the cost of producing alfalfa in various harvesting packages differs. Harvesting costs are typically less for round bales, but the alfalfa market also discounts prices paid for them. Large square bales are typically the most costly to produce. Some buyers may pay a premium for large square bales, but some may not. Small rectangular bales lie in between the other two types in terms of harvesting costs and are typically not discounted by buyers.

Seasonal Prices

Timing of alfalfa sales also affects growers' marketing plans. Alfalfa, like most agricultural commodities, exhibits a seasonal price pattern due to seasonal supply or demand, or a combination of both. Seasonal price index values indicate how a given month's price differs from the annual average price over a specified period of years (often 10 years).

From the mid-1980s to the mid-1990s, alfalfa prices on average in Oklahoma have been lowest shortly after the production marketing year begins (reaching a low in the May-June period). Prices then increase gradually until peaking in January before declining in February and March, and then dropping sharply until the new crop harvest begins again. Prices below the annual average price occur during the primary alfalfa harvesting months. The January price was 6.2 percent above the annual average price. Similarly, in June, the prices over the past ten years averaged 7.7 percent

Table 8-1. Relation between alfalfa hay quality and market price, HAYMARKET 1992-93

Quality Trait*	Price Change
1 unit increase in **RFV**	$0.32 per ton increase
1% point increase in **TDN**	$1.65 per ton increase
1% point increase in **CP**	$2.55 per ton increase
1% point decrease in **NDF**	$1.63 per ton increase
1% point decrease in **ADF**	$1.64 per ton increase

*RFV = Relative Feed Value; TDN = Total Digestible Nutrients; CP = Crude Protein; NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber. See Chapter 5, "Forage Yield and Quality" below the annual average price.

Storage and Out-of-Field Marketing

A high price is not the sole goal in marketing, though price is certainly important. Accepting a lower price for alfalfa hay sold from the field during the lower-price months may return more than handling and storing alfalfa while waiting for a higher price during later months. Hay that is stored shrinks (loses moisture) as it cures. See Chapter 6, "Hay Handling and Storage," for more information.

On average, about 10 percent fewer pounds of the same hay will be sold from storage as will be sold from the field at harvest. One ton from the field at $90 per ton is equivalent to about $100 per ton of the same hay after a 10-percent shrink. In addition, storing hay requires storage facilities, handling, and having your money tied up in inventory (unsold hay) for the storage period. However, if the annual average price is $100 per ton, the average price in June will be $92.30 (based on the latest 10-year price indexes) compared to $106.20 in January, a difference of $13.90 per ton. In some years, the within-year, peak-to-valley difference is considerably more, though it can also be less. Therefore, in some cases, storing alfalfa for a higher price is worth the added cost. One strategy alfalfa growers might consider is to market lower-quality alfalfa hay from the field and store higher-quality alfalfa to market later in the year.

Markets for Oklahoma Alfalfa

Estimated average daily alfalfa hay consumption (pounds per head per day) over a 12 month period by species according to animal scientists was: dairy cattle, 12.3; beef cattle, 3.6; feedlot cattle, 1.6; horses, 6.2; and sheep, 1.6. These amounts were used to estimate alfalfa consumption by state.

The difference between alfalfa production and estimated consumption in each state was used as an indicator of alfalfa surplus or deficit in each respective state. Major deficit states are most consistently in the southern region of the U.S. Texas is by far the largest deficit state. Alfalfa surplus states tend to be in the northern and western states.

Several least-cost transportation models were estimated. In all cases, the model found a least-cost movement of alfalfa from production to consumption regions given the assumed set of transportation costs. Truck size and transportation rates vary from state to state. Agronomists were asked to identify common load sizes and transportation rates for alfalfa hay. For load size, a 44,000-pound size load was chosen. Rates chosen were $1.00 per mile for higher-quality alfalfa and $1.65 per mile for lower-quality alfalfa.

Results for the 1995 base model suggest all higher-quality alfalfa produced in Oklahoma should be shipped to Texas, and most lower-quality alfalfa should be fed in Oklahoma.

Results for an assumed 20 percent increase in Oklahoma alfalfa production are interesting in that total exports from Oklahoma to other states increase, but the composition of exports changes. In the base model, Oklahoma shipped 433,000 tons of high-quality alfalfa and 95,000 tons of lower-quality alfalfa to Texas for dairy demand. About a million tons of lower-quality alfalfa remain in Oklahoma to satisfy the alfalfa demand for nondairy livestock.

With an assumed 20 percent increase in production, Oklahoma will ship significantly more alfalfa to Texas, both for dairy and nondairy demand. The model indicates that 572,000 tons of high-quality alfalfa is exported to Texas to satisfy dairy demands in that state. Another 823,000 tons of lower-quality alfalfa is shipped to Texas to satisfy nondairy demand, while 338,000 tons remains in Oklahoma to satisfy nondairy demand.

Therefore, a 20 percent increase in Oklahoma's alfalfa production likely would result in more alfalfa, both higher and lower-quality, being exported to Texas than in the 1995 base model. This suggests that increases in alfalfa production would likely increase alfalfa exports to Texas, but not all at dairy-quality alfalfa prices.

Chapter 9
Irrigation

In Oklahoma, irrigating alfalfa is more art than science, but adhering to certain practices makes irrigation profitable. During peak production periods, alfalfa uses water at the rate of more than three-tenths of an inch per day. Many irrigation systems in Oklahoma are not designed to meet water demands fast enough to start irrigating alfalfa in the summer and catch up while plants are actively growing.

If a system can deliver two inches of water per week for three weeks, this amounts to six inches of water between harvests. Alfalfa needs about six inches of water available to its roots to produce a ton of dry matter. Based on this rule-of-thumb, two inches per week is only enough water to produce one ton per acre per harvest with minimal rainfall.

Table 9-1 shows the normal intake rate and storage capacity for typical alfalfa soils in Oklahoma. To estimate the total available water storage capacity of a given soil, multiply the number in the water storage capacity (right column) by the depth of the rooting zone. Many alfalfa soils have a water holding capacity of more than two inches per foot of depth. Soil with a rooting zone six feet deep can store 12 inches of water. Some good alfalfa soils in Oklahoma have greater water storage capacities because of greater depth. If the crop depletes the available water content, it will become stressed to such a degree that growth is stunted. Normally, irrigation should occur when no more than 60 percent of the available soil water has been depleted from the effective root zone. This means that the crop should be irrigated after 5-6 inches of water have been used. The net amount of water to be replaced at each irrigation should be equal to the amount that has been used.

The period of time that elapses before this amount of water is used varies during the season, according to weather conditions. If the peak daily water use during the growth cycle is 0.29 inches per day, five inches of water should be sufficient to supply alfalfa for the first 18-22 days after harvest and removal of the hay, without subjecting the crop to significant water stress. An additional 2.5 inches of irrigation water is normally needed to see the crop through to cutting time, unless some rainfall occurs. Smaller, more frequent irrigations may be applied; however, this normally leads to inefficient water use. This is because immediately after irrigation, the water use rate is elevated due to surface soil and vegetation wetness. The more often irrigation occurs, the more significant this excess evaporation becomes.

Various estimates indicate that 10-25 percent of Oklahoma's alfalfa is irrigated. That is a relatively small portion, but correctly irrigated fields produce much higher forage yields. Alfalfa irrigation in western parts of the state during summer may be profitable

Table 9-1. Typical irrigation characteristics for a variety of soil textures

Soil Texture	Intake Rate	Available Water Storage
	inches per hour	inches per foot of soil
Clay	0.1	2.0
Silty Clay Loam	0.3	2.2
Silt Loam	0.5	2.5
Loam	0.7	2.0
Fine Sandy Loam	1.0	1.5
Loamy Fine Sand	1.5	1.1
Fine Sand	3.0	0.8

because of the low probability of heavy rains following irrigation. Irrigation during the fall and winter will almost always pay for itself in increased yields with little possibility of hurting stand life.

Irrigation systems may be sized to meet peak water use demand of the crop during the driest period of the growing season. Systems may be sized to supply the complete water needs of the crop, assuring maximum production even during sustained drought conditions. More commonly, they are sized to supplement normal growing-season rainfall and assure maximum potential production in approximately six years out of ten. An irrigation system designed to supplement normal rainfall has a smaller water supply and smaller equipment components than a system that can supply total water needs, and is normally less expensive.

Scheduling Irrigation

Alfalfa's total water demand peaks in July at an average daily demand of about three-tenths of an inch per day. For an irrigation system that operates 18 hours a day with a 75-percent application efficiency, a water supply of nearly 10 gallons per minute must be available for every acre to be irrigated. This means that to meet the total water requirement of 40 acres of alfalfa when there is no rainfall, 400 gallons per minute must be supplied by the system. Most irrigated farms are larger and require proportionately higher capacity.

It is important to fill the soil profile in late winter while alfalfa is dormant and before soil temperatures warm to above 60°F. This is important because it is nearly impossible to catch up during the growing season. Watering for three weeks between cuttings for a two ton per acre yield requires over three inches of water per week and may result in standing water, which is potentially damaging to alfalfa plants during the summer. Saturating soils when the soil temperature is above 60°F should be avoided. This is a condition favorable for the development of *phytophthora* root rot, which hastens stand decline.

Economics of Irrigation

The economics of alfalfa irrigation are complex, and irrigation does not necessarily always mean increased hay production and profits. Table 9-2 contains the most important input and output factors dealing with irrigation economics and illustrates how some of the variables work together. Any particular farm may have a set of factors somewhat different from those shown and the costs and returns can be recalculated. Not surprisingly, the data show that benefits from irrigation increase as effective rainfall decreases. Situation five (wet) with 40 inches of rainfall lost yield with irrigation. The dry situations (one and four) increased yield greatly, and irrigation was profitable.

Table 9-2 shows that returns above the specified costs with irrigation may vary from \$105 per acre to \$765 per acre. Returns without irrigation may vary from \$84 per acre to \$533 per acre. Both ranges are wide because of the influence of many different cost and benefit factors.

Summer rains following irrigation cause problems, especially in eastern parts of the state. Once the soil is at field capacity from irrigation, rain makes water stand and delays harvests, leading to reduced forage quality. In addition, standing water when the soil temperature is higher than 60°F promotes root rot.

Improper summer irrigation can increase weed problems and reduce yields as well as stand life. Average rainfall for December, January, and February combined is only 3-6 inches (depending on the part of the state). If alfalfa fields are not irrigated during the dormant season, the next season begins in a water deficit. Irrigation during the late fall, winter, and early spring is easier than irrigation during the summer. When soil temperatures are cool, there is little danger of excess water causing root rot. There is also much less danger of scald during the cool seasons.

Producers irrigating seedling alfalfa should avoid standing water during hard freezes. Hard freezes, alternating with warming periods, can cause seedlings to heave out of the ground.

Obviously, one problem associated with winter irrigation is freezing pipes. Pipes should be drained before temperatures become dangerously low, but most systems automatically drain aboveground pipes to avoid damage.

Many alfalfa fields in Oklahoma are subirrigated naturally by high water tables. Subirrigation of alfalfa can be productive and profitable, furnishing ample supplies of water without wetting the upper rooting regions where root-rotting organisms thrive. This is an important factor when selecting a site for a new stand.

Table 9-2. Effects of irrigation on alfalfa hay yield and economics with varying rainfall and other factors

Factors	**Effective Rainfall**				
	12 in.	**30 in.**	**30 in.**	**18 in.**	**40 in.**
Yield w/o irrigation (tons per acre)	2.4	5.00	5.00	3.00	6.67
Yield with irrigation (tons per acre)	10	8	12	6	6
Water needs (inches per ton of hay)	5	6	6	6	6
Water required (inches)	50	48	72	36	36
Effective rainfall (inches)	12	30	30	18	40
Irrigation required (inches)	38	18	42	18	-4
Irrigation required (gallons per acre)	1,031,791	488,743	1,140,400	488,743	-108,609
Pumping capacity (gal per min)	1000	800	450	800	450
Pumping hours per acre per year	17.20	10.18	42.24	10.18	-4.02
Field size (acres)	120	120	120	120	120
Pumping cost ($ per acre-inch)	$7.50	$7.50	$7.50	$8.50	$8.50
Pumping cost ($ per acre)	$285.00	$135.00	$315.00	$153.00	-$34.00
Yield increase due to irrigation	7.6	3	7	3	-0.67
Selling price of hay (dollars per ton)	$90.00	$125.00	$125.00	$125.00	$125.00
Receipts (with irrigation) ($ per acre)	$900.00	$1,000.00	$1,500.00	$750.00	$750.00
Receipts above irrigation costs ($ per acre)	$615.00	$865.00	$1,185.00	$597.00	$784.00
Receipts w/ o irrigation ($ per acre)	$216.00	$625.00	$625.00	$375.00	$833.33
Other expenses ($ per acre) for					
irrigated system($35 per acre), **owned equipment**	$350.00	$280.00	$420.00	$210.00	$210.00
irrigated system ($51 per acre), **custom harvest**	$510.00	$408.00	$612.00	$306.00	$306.00
rain-fed system ($45 per acre), **owned equipment**	$108.00	$225.00	$225.00	$135.00	$300.00
rain-fed system ($55 per acre), **custom harvest**	$132.00	$275.00	$275.00	$165.00	$366.67
Returns above specified costs for ($ per acre)					
irrigated system & owned equipment	$265.00	$585.00	$765.00	$387.00	$574.00
irrigated system & custom harvest	$105.00	$457.00	$573.00	$291.00	$478.00
rain-fed system & owned equipment	$108.00	$400.00	$400.00	$240.00	$533.33
rain-fed system & custom harvest	$84.00	$350.00	$350.00	$210.00	$466.67

Table 9-3. Sources of information, assumptions, and calculations related to the economics of irrigating alfalfa

Information provided by producer	Comments and Normal Ranges
Yield with irrigation (tons per acre)	5 to 10 tons per acre
Water needs (inches per ton of hay)	5 to 6 inches per ton
Effective rainfall (inches)	Includes rainfall, minus runoff, plus run-on, plus water available from subirrigation
Pumping capacity (gallons per minute)	300 to 1200 gpm
Field size (acres)	
Pumping cost ($ per acre-inch)	Varies with energy source, pumping depth, irrigation system type.
Sprinkler system powered with electricity	($5 to $6 per acre-inch).
Sprinkler system powered with natural gas	($6 to $9 per acre-inch).
Assumptions	These expenses range normally from $30 to $60. Under special situations the range may be wider.
Other expenses in irrigated system ($35 per acre), **owned equipment**	includes prorated establishment costs, insecticide, herbicide, fertilizer, operating capital, machinery labor, machinery, fuel, lube, repairs, interest, depreciation, taxes, insurance, etc.
Other expenses in irrigated system ($51 per acre), **custom harvest**	same as above plus swathing, baling, hauling
Other expenses in rain-fed system ($45 per acre), **owned equipment**	includes prorated establishment costs, insecticide, herbicide, fertilizer, operating capital, machinery labor, machinery, fuel, lube, repairs, interest, depreciation, taxes, insurance, etc.
Other expenses in rain-fed system ($55 per acre), **custom harvest**	same as above plus swathing, baling, hauling
Calculated Values	**Based on**
Water required (inches)	yield X inches of water per ton of hay
Irrigation required (inches)	required less rainfall
Irrigation required (gallons per acre)	7.48 gal per cubic ft
Pumping hours per acre per year	gal required per capacity per 60 minutes per yr
Pumping cost ($ per acre)	inches required X $ per acre-inch
Yield w/o irrigation (tons per acre)	effective rainfall per inches per ton
Receipts (with irrigation) ($ per acre)	gross income
Receipts above irrigation costs ($ per acre)	less cost for irrigation
Receipts w/o irrigation ($ per acre)	gross income

Irrigation System Types

Soil type also affects the type of irrigation system that can be used to supply water, and the rate at which water is applied. Soil permeability or intake rate determines the rate at which water can be applied, which is largely determined by soil texture. Typical intake rates for various soil textures are given in Table 9-1. Specific values for a given soil type should be determined by infiltration tests or by consulting the USDA County Soil Survey.

With **sprinkler systems**, the precipitation rate of the system should not exceed the ultimate intake rate of the soil. If the system applies water too rapidly, water will pond on the soil surface and run off of sloping fields. The precipitation rate of a **hand-moved** or **side-roll system** is determined by the discharge of individual sprinklers and the spacing between sprinklers. For a continuously moving system, such as a **center-pivot** or **lateral-move system**, the precipitation rate is determined by the individual sprinkler discharge, the sprinkler spacing, and the speed of movement of the system. Alfalfa is adaptable to virtually all types of sprinkler systems. Side-roll and center-pivot systems are the most commonly used systems, but hand- moved and **high-volume gun systems** may be used also.

Alfalfa can also be irrigated by **surface irrigation** methods. **Border irrigation** can be practiced on smooth, level, or uniformly sloping fields. Small cross-section **furrows**, or **corrugations**, can be used to control the movement of water across less uniform surfaces. To achieve an acceptable level of application efficiency, the permeability of the soil must fall within fairly narrow limits. If the intake rate is too high, the water cannot be spread over any but the shortest length of run before it is completely absorbed. If the intake rate is too low, extremely low flow rates must be used with very long application times to prevent excessive runoff.

Subsurface drip irrigation is a system being used increasingly by alfalfa producers across the country. Because the tubing of a subsurface drip irrigation system is normally buried 12-15 inches below the ground, the soil surface is not wetted appreciably during normal operation. This dramatically reduces evaporation losses and improves irrigation application efficiency to the 90-95 percent range. The spacing of subsurface drip lateral lines depends largely on soil texture, but will usually be from 5-8 feet.

Adequate filtration and frequent system flushing is necessary to prevent blockage of emitters by sediment. Occasional treatment of the system with acid may be necessary to prevent mineral build-up in emitter outlets, and treatment with chlorine may be required to eliminate blockages by biological growths such as bacterial slime and algae. With proper maintenance, subsurface drip systems can work effectively for 10-20 years.

Precise control of the timing and amount of irrigation, improved water use efficiency and low labor requirement make them an attractive alfalfa irrigation option despite their relatively high initial cost. The high application efficiency of these systems makes them especially viable in areas with limited irrigation water or where water and pumping energy are very expensive.

Water Quality

As with most crops, yield increases realized when irrigating alfalfa can be significantly affected by the quality of the irrigation water. The presence of dissolved mineral salts in the water can result in an increase in the energy level required for plants to remove water from the soil pores. Some crops are more readily affected by salinity problems than others. Alfalfa is rated as being moderately sensitive to salinity effects. Alfalfa first experiences a yield reduction when the saturated soil extract measures an electrical conductivity of 2.0 mmho per cm (millimhos per centimeter). This generally corresponds to irrigating with water that has an electrical conductivity of 1.3 mmho per cm. Beyond this level, relative yield is reduced by approximately seven percent for each mmho per cm increase in conductivity, leading to a zero yield when conductivity of the extract reaches about 16 mmho per cm.

Certain mineral elements have toxic effects on crops. Alfalfa is tolerant of the toxic effects of sodium in soil and water. In nonsaline conditions, alfalfa suffers no direct adverse effects from sodium. Exchangeable sodium in excess of 15 percent causes deterioration of the physical condition of the soil. As a result, water infiltration and percolation are greatly reduced. Alfalfa is tolerant of boron content in irrigation water. No visible toxic effects are observed until the boron content of irrigation water reaches three milligrams per liter.

Normally, slightly saline water can be used for irrigating alfalfa without harmful effects because relatively large quantities of water are required and the application of large volumes tends to push the highly concentrated salts down in the soil profile. Irrigation water quality plays an important role in stand establishment. Saline water used to irrigate a new stand can cause serious problems. During germination and emergence, a large volume of water will wash out seeds, but repeated uses of salty water followed by evaporation tends to concentrate the salts in the zone of germination and root elongation. The high salt concentration in the germination zone causes more energy to be needed for imbibition by seeds, and the salts may be toxic to new roots.

Before considering development of an irrigation system or using a source of water of unknown salinity, it is advisable to have the water supply tested to determine its suitability for irrigation purposes. Irrigation water can be tested by the Soil, Water, and Forage Testing Laboratory at Oklahoma State University.

Chapter 10
Alfalfa Seed Production

Historically, alfalfa seed production was centered in the Great Plains, where hay producers used old hay fields with thin stands. Between 1936 and 1945, Oklahoma ranked second in the United States in alfalfa seed production. Seed yields were 50-400 pounds per acre, and seed quality was frequently questionable. Recently, seed production has become specialized in the western states, where producers plant in wide rows with one to three pounds of seed per acre and obtain yields of 500-2000 pounds per acre of high-quality seed.

Despite the fact that seed production sometimes accounts for up to ten percent of the revenue from alfalfa in Oklahoma, it can best be considered a catch-as-catch-can operation for the majority of seed producers. Most alfalfa seed is produced in the western part of the state from fields that were originally sown for hay production but that now have declining stands.

Alfalfa seed producers usually rely on wild bee pollinators exclusively or provide minimal numbers of honeybees. Only rarely do Oklahoma seed producers use alfalfa leafcutting bees or other contract pollination services. They usually harvest one or two cuttings of hay from a field, then let the next crop mature seed in August or September. Rainfall and soil moisture conditions in spring and early summer are major factors determining when alfalfa producers try for a seed crop. When moisture is limiting and the prospects for a good hay crop are poor at second or third harvest, alfalfa stands are allowed to mature seed. Thus the farmer exchanges two hay crops (with the accompanying labor and harvest costs) for one crop of seed. Even if seed yields are low (100 pounds per acre), farmers may make more money from seed than with two poor hay crops.

Alfalfa seed yields generally average from 150-200 pounds per acre statewide; however, individual yields of 500-1100 pounds per acre have been reported. After the seed crop is harvested, if there is adequate moisture, another hay crop may be harvested, or the stand may be grazed by cattle during the fall.

Generally, high rainfall seasons are not favorable for seed production in Oklahoma. For this reason, when moisture conditions are favorable for hay production, no seed crop will be harvested. This is why most producers consider it a catch-as-catch-can crop.

Alfalfa produces flowers over a period of approximately seven weeks. When a flower is pollinated, the seedpod develops and matures in 3-5 weeks. Under reasonably good conditions, each pod contains 3-5 seeds. Under conditions of high insect pest pressures, many pods do not contain a viable seed (see Chapter 2, "Insect Pests in Alfalfa Grown for Seed").

Most reliable alfalfa seed production in Oklahoma comes from stands harvested for hay about May 15 and left for seed until August. Seeds are mature about four weeks after pollination, and it takes another three weeks for them to dry. If an alfalfa field blooms for three weeks, that's about 10 weeks from first bloom to seed harvest. To harvest seed in mid-August, alfalfa should be cut about May 15, as illustrated in Table 10-1.

When the last harvest before seed production occurs before mid-May, excessive forage may be produced, and pollinators are inactive. When the last hay harvest occurs in June or July, seed harvest is delayed until after the be-

Table 10-1. Reliable seed production schedule for western Oklahoma

Cut for Hay	Grow Plants	1st Bloom	Blooming		Maturing		Drying	Harvest Seed
May 15	→	June14	→	July 5	→	July 26	→	August 16

ginning of planting season, and the probability of chalcid damage is higher than early-season seed crops. Damage by *Lygus* bugs (flower-drop and shrunken seeds) is also more severe when seed set is delayed until late summer. (See Chapter 2, “Insect Pests in Alfalfa Grown for Seed.”)

Seed fields normally have high populations of *Lygus* bugs, and controlling this insect may increase seed yields dramatically. Much of the flower drop in seed production fields is due to injury from *Lygus* bugs, but is most often blamed on dry weather. Early morning spraying for *Lygus* bugs when alfalfa first begins to bloom minimizes damage to pollinators. If honeybee hives are on trailers, they should be removed from the field for at least a day when spraying for *Lygus* bugs. In addition, seed producers should choose insecticides that are the least harmful to pollinators.

Windrowing Before Threshing: Alfalfa is usually cut and allowed to dry in the windrow before combining. This is an extremely vulnerable period for seed harvest. Hard rains accompanied by high winds can cause pods to pop open, allowing seeds to shatter or germinate in the windrow before threshing.

Seed fields should be swathed when about 60 percent of the seedpods have turned light to dark brown. Many pods that set late are still yellow at this time. Drying in the swath to about 14 percent moisture prepares the crop for combining. Do not crimp the crop during swathing.

Chemical Desiccation: When chemical desiccation of a standing seed crop is used, it can be ready for direct combining within 3-4 days after desiccation. Green pods do not ripen after desiccation, so nearly all the pods should be brown or yellow before applying the desiccant. Check the latest regulations and read the label before deciding to use a desiccant.

Regardless of how alfalfa is dried for seed harvest, clearance between the combine cylinder bar and concave should be 1/8-3/8 inch. Cylinder speed should be about 4000 feet per minute (850 RPM for an 18-inch diameter cylinder).

Specialized Seed Production: While most seed is produced in solid stands, research in Oklahoma has demonstrated low sowing rates (one to three pounds per acre) in 24-40 inch rows improves the reliability of alfalfa seed production. Under favorable weather conditions and correct management, fall-sown seedling stands can produce up to 500 pounds per acre the following August. In limited commercial production fields, this type of seed production practice has demonstrated that specialized seed fields may produce surprising forage yields, up to 2.5 tons per acre in late May and 1-2 tons per acre after the seed is harvested.

Chapter 11
Economics of Producing Alfalfa

Alfalfa growers make a variety of management decisions that affect profitability. These include variety selection, fertility program, control of insects and weeds, harvest method, storage, and marketing. Many aspects of production and marketing combine to affect both total revenue and total costs. Since alfalfa is a perennial crop, total costs are divided into establishment costs and annual operating costs. Establishment costs are incurred the year of establishment but can be averaged over the life of the stand. Annual operating costs occur each production year.

Many management practices affect both revenue (price received and yield) and costs (establishment and annual costs). Price depends in part on quality, which in turn is affected by establishment practices and annual production practices. Yield is also affected by establishment practices and annual production practices.

Annualized establishment costs depend on stand life. Stand life, in turn, depends on both establishment practices and annual production practices. Therefore, establishment and annual production practices are both very important. Both affect profitability since they each contribute jointly to returns (i.e., yield and quality) and to costs. Whenever possible, the economics of each major factor has been included in the preceding chapters.

Four management practices were integrated and the effects measured in research studies by OSU. For example, one five-year study considered the effects from varieties, weed control, insect control, and end-of-season harvest method. Table 11-1 summarizes returns for selected combinations of management practices. For the research, these practices nearly replicate what might be considered best management practices.

The best return ($2841.00 for five years = $568.20 per year) resulted from a multiple-pest resistant variety where weeds and insects were controlled and fall growth was grazed. There were reduced returns associated with all four management factors studied. For example, when OK08 was used in place of the multiple-pest resistant variety in combination with the other three best management practices, a 15 percent loss resulted. Similar comparisons for the other three management factors were as follows; eight percent loss with fall cutting, seven percent loss when weeds were not controlled, and six percent loss when insects were not controlled.

Table 11-1. Total adjusted five-year dollar returns per acre for integration of four alfalfa management practices (variety, insecticide, herbicide, and fall harvest practice)

	Fall Harvest Practice			
	Fall Cut		Fall Graze	
Insecticide	**No Herbicide**	**Herbicide**	**No Herbicide**	**Herbicide**
	Multiple-pest Resistant Variety			
No Insecticide	$2,469*	$2,541	$2,605	$2,673
Insecticide	$2,654	$2,613	$2,641	$2,841
	OK08 Variety			
No Insecticide	$1,989	$1,987	$2,179	$2,174
Insecticide	$2,073	$2,246	$2,290	$2,422

*Returns for five years ($ per acre)

Stand Life

Using a sample budget for an alfalfa enterprise and excluding capital costs for land, buildings, and equipment, establishment costs represent over 35 percent of the first year's costs. (See **Table 11-1**.) However, if the stand survives eight years and establishment costs are averaged over the eight-year period, establishment costs represent only seven percent of the costs for year eight, assuming constant annual costs. Stand life is dependent on many factors, so extending the productive stand life to as many years as economically possible requires long-term planning combined with timely execution of annual management practices. Sometimes, not following a recommended practice initially appears as a cost savings but ultimately results in lower plant population, less vigorous plants, lower yields, poorer quality alfalfa, and reduced stand life. Consequently, ignoring recommended practices may be more costly than following them.

Stand life is especially important to profitability of the alfalfa enterprise, but at some point the stand needs to be replaced with an interim crop and later reestablished. The yield pattern of an alfalfa stand over several years is difficult to estimate due to weather and other factors. Nevertheless, the stand is most productive in the early to mid years and trails off in later years. One approach is to allocate all establishment costs to the first crop year. Then total costs each year (establishment plus operating costs in year one and only operating costs in subsequent years) are divided by each year's yield to determine the marginal or added cost per ton for maintaining alfalfa another year. Marginal or added costs are high the first year due to establishment. Then the added costs of maintaining the alfalfa stand decline and remain relatively low during the higher-yield years. Finally, as annual yields decrease in later years of the stand, marginal costs increase.

Growers can track their yield pattern and know when yields are decreasing and marginal costs are increasing. At some point, marginal costs increase above the expected marginal or added revenue from each ton of alfalfa sold. Marginal or added revenue per ton is simply the expected selling price. To be profitable, the added revenue from maintaining the alfalfa stand one more year must equal or exceed the added cost of maintaining the stand one more year. Consequently, whenever expected marginal revenue (expected sale price per ton for the year) exceeds expected marginal costs (annual operating costs per ton), the stand should be maintained for another year. When expected marginal revenue drops below expected marginal costs, the stand should be plowed under.

Table 11-1. Importance of stand establishment practices and cost savings of omitting practices when capital is limited

Establishment Practice	New Stand	Probable Losses To* Yield	Probable Losses To* Stand Life	Short-Term Cost Savings	Comments
FERTILIZER & LIME					
Soil Test	Always Critical	Always Critical	Always Critical	$10/field	Soil test should be taken each year.
Nitrogen fertilization	Important if N is very low	Not Critical	Not Critical	$7/acre	
Phosphorus fertilization	Critical if P is below 75 percent sufficient	Critical	Critical	$ 0.28/lb of P_2O_5/acre	4-year supply could be applied before establishment. Production lost when P sufficiency is below 85 percent. Higher rates will be required after establishment.
Potassium fertilization	Critical if K is below 75 percent sufficient	Critical	Critical	$ 0.18/lb of K_2O/acre	Should be applied before establishment, and each year according to soil test.
Lime	Important if pH is below 6	Important if pH is below 6	Critical if pH is below 6	$20/ton	Much less efficient when applied on the soil surface after establishment.
LAND PREPARATION					
Deep tillage	Little or no importance	Important if hard pan exists	Rarely Critical	$10-12/acre	Cannot be corrected later.
Disk to incorporate fertilizer & lime	Important if high rates are required	Important if high rates are required	Important if high rates are required	$5-10/acre	Cannot be corrected later.
Level and drain	Always Critical	Always Critical	Always Critical	$5-15/acre	Cannot be corrected later.

Table 11-1 (Cont.). Importance of stand establishment practices and cost savings of omitting practices when capital is limited

Establishment Practice		Probable Losses To*		Short-Term Cost Savings	Comments
	New Stand	Yield	Stand Life		
		SEEDBED PREPARATION			
Shallow disk	Always Important	Not Critical	Not Critical	$ 5-7/acre	Cannot be corrected later.
Spring tooth	Important	Not Critical	Not Critical	$ 4-8/acre	Stand establishment importance depends on state of seedbed. Cannot be corrected later.
Spike tooth	Usually Important	Not Critical	Not Critical	$ 4-8/acre	Stand establishment importance depends on state of seedbed. Cannot be corrected later.
Cultipacker	Perhaps Important	Not Critical	Not Critical	$ 5-7/acre	Stand establishment importance depends on state of seedbed. Cannot be corrected later.
		SEED AND SEED TREATMENTS			
High quality	Always Important	Always Important	Always Important	$ 10-15/acre	See "Variety Choice" Cannot be corrected later.
Well-adapted variety	Always Critical	Always Critical	Always Critical	$ 5- 10/acre	See "Variety Choice" Cannot be corrected later.
Inoculum	Always Important	Always Important	Always Important	$1-2/acre	Practically cannot be corrected later.
Pre-inoculated seed	Not Critical	Not Critical	Not Critical	$ 1-2/acre	Practically cannot be corrected later.
Fungicide treatment	Sometimes Critical	Not Critical	Not Critical	$1-2/acre	Cannot be corrected later.

INSECT CONTROL

Aphids	May Be Critical	May Be Critical	May Be Critical	$5-20/acre	Field scouting is critical
Caterpillars	May Be Critical	May Be Critical	Rarely Critical	$5-15/acre	Field scouting is critical
Grass-hoppers	May Be Critical	Rarely Critical	Rarely Critical	$5-15/acre	Field scouting is critical. May treat borders only.

WEED CONTROL

Herbicide					
Low competitive broadleaf weeds	Usually Not Important	Not Important	Not Important	$16/acre	Field scouting is critical to determine weed identity and density. Plant density of new seedlings would only be reduced if density of noncompetitive weeds exceeded alfalfa seedling density.
Competitive broadleaf weeds	May Be Critical	May Be Critical	May Be Critical	$11-20/acre	Field scouting is critical to determine weed identity. Yield and stand life may be reduced when weed density is 1/sq. ft. and stand loss with 3 or more.
Competitive weedy grasses	May Be Critical	May Be Critical	May Be Critical	$13-23/acre	Same comments as with broadleaf weeds above when high nitrogen levels in soil. Grass competition only critical when grass out-grow and shade alfalfa.
Low competitive grassy weeds	Usually Not Critical	Not Critical	Not Critical	$5-20/acre	Field scouting is critical to determine weed identity. Only with more grass than alfalfa would establishment of alfalfa be reduced.
Preplant incorporated	Rarely Important	Not Critical	Not Critical	$16/acre	Postemergence herbicides can be applied if a weed problem develops.

* All "Establishment Practices" represent decisions producers must make and are, therefore, at least somewhat important to successful alfalfa stand establishment. Ratings of "Important" and "Critical" address long-term losses that should be balanced against "Short-Term Cost Savings" if a practice is skipped or cut short. Those marked "Critical" can have drastic effects on stand establishment, potential yield, or stand life. Those marked "Important" can have effects on stand establishment, potential yield, or stand life, but they are not normally devastating. Modifiers of "Important" and "Critical" indicate how often that decision will impact stand establishment, potential yield, or stand life. These can be used to help judge if the "Short-Term Cost Savings" are worth the risk, even when capital is limiting. See discussions on each of these topics to see how the practices impact production.

Appendix
Other Sources of Alfalfa Information

For alfalfa information available on the web, see **alfalfa.okstate.edu/alfalfa** and click on the following links:

- Alfalfa Alert
- Alfalfa Production Calendar
- Alfalfa Production Keywords
- Oklahoma Alfalfa Hay & Seed Association
- Oklahoma Alfalfa Hay & Seed Association NEWS
- Variety Test Results

For additional information on the web:

- Alfalfa Harvest Management Discussion with cost-Benefit Analysis E-943
  HTML Format alfalfa.okstate.edu/alfalfa/pub/harv-943.htm
  PDF Format alfalfa.okstate.edu/alfalfa/pub/e-943.pdf

- Alfalfa Production and Pest Management in Oklahoma E-826
  okstate.edu/OSU_Ag/agedcm4h/pearl/e826/

- Alfalfa Stand Establishment Questions and Answers E-949
  alfalfa.okstate.edu/alfalfa/pub/stand-949/stand-est.htm

- Images Related to Alfalfa Production and Pest Management
  alfalfa.okstate.edu/alfalfa/database/images/imagedata.htm

Other information can be found in:

- "Herbicide Suggestions" in *Extension Agents' Handbook* available at all county offices

- "Insecticide Suggestions" in *Extension Agents' Handbook* available at all county offices

Foreword

This publication is designed to assist alfalfa producers, Extension Educators, Certified Crop Advisors, and Agriculture Alfalfa Industry to make effective, profitable, and environmentally sound management decisions on alfalfa production and marketing. It represents the integrated efforts of many people in the various disciplines of Oklahoma Cooperative Extension Service and the Oklahoma Agricultural Research Station at Oklahoma State University. A special effort was made to integrate all aspects of alfalfa production and to relate the various sections within the overall production framework. In addition, partial budgets were calculated for many of the management alternatives so producers could make some sound management decisions, based on their system.

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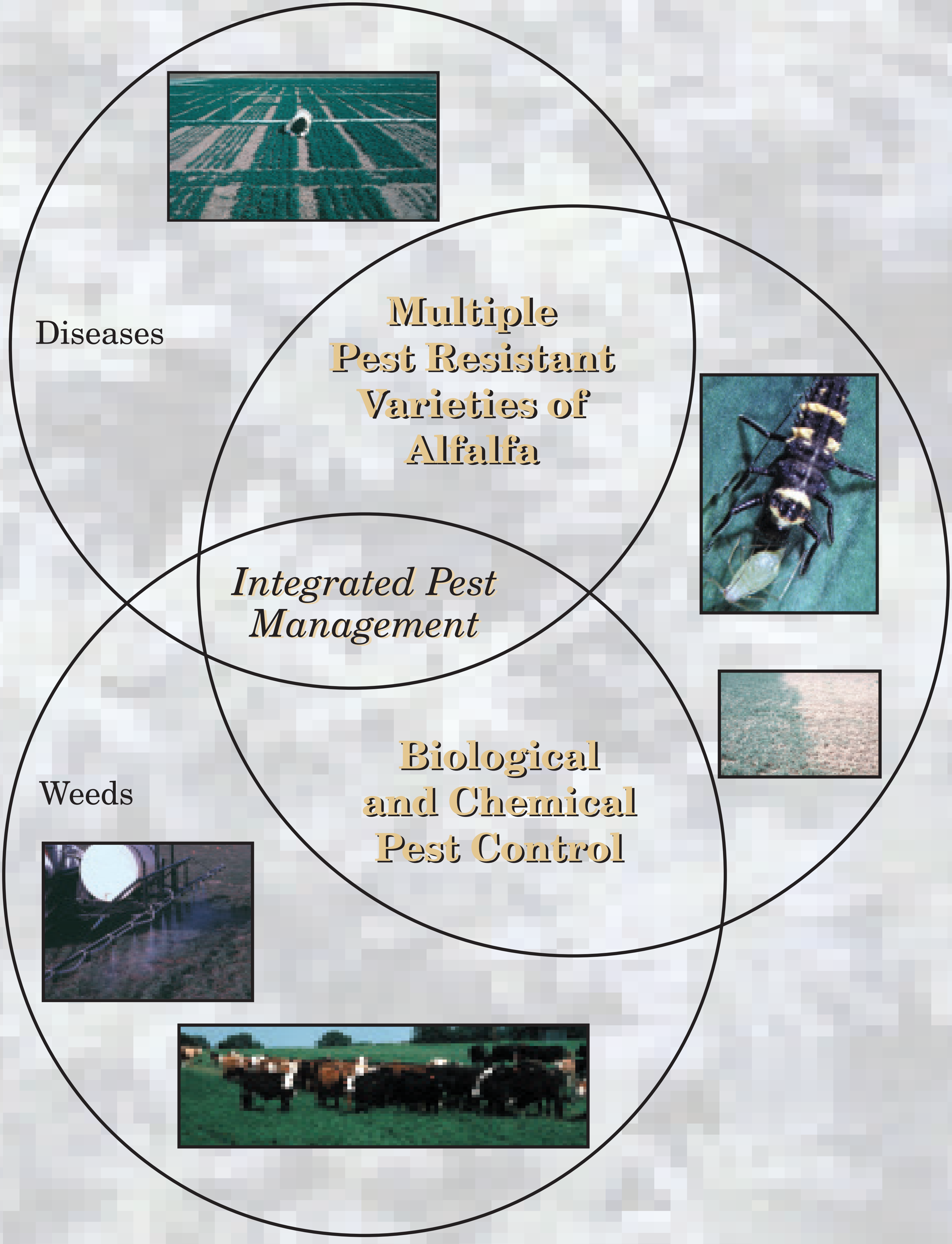
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