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Alfalfa Production Handbook

Kansas State University Agricultural Experiment Station
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Cultural Practices

Variety Selection

Selecting the best alfalfa varieties is one of the most important decisions producers make in developing a good forage-production system. Selecting alfalfa varieties is a 5- to 10-year investment. It is important to buy quality seed of certified varieties with high germination percentages. Planting high-yielding, adapted varieties not only ensures good yields but also healthy and vigorous stands 1 to 2 years longer than poorly adapted varieties.

Each year, the Kansas Agricultural Experiment Station publishes an alfalfa variety performance report. This publication contains yield data of the latest varieties at the test sites. From these test results, producers can determine varieties that are best suited to their environments. Copies of alfalfa variety performance reports can be obtained at K-State Research and Extension county offices and at Kansas experiment fields and stations or via the World Wide Web at *www.ksu.edu/kscpt*.

When selecting alfalfa varieties, producers not only need to be aware of yield potential but also of disease and insect resistance, fall dormancy, and winter hardiness. These varietal characteristics determine stand persistence and productivity.

It is important to select varieties that are highly resistant to bacterial wilt, leaf and stem diseases, and crown rots, such as phytophthora root rot. Resistance to insect pests, including the spotted alfalfa aphid and pea aphid, has been incorporated into some varieties, and they are recommended. Varietal resistance to the alfalfa weevil has not been achieved; however, a few varieties are tolerant to low levels of weevil infestations. Increased insect resistance will likely be conferred by the use of glandular hairs in new cultivars.

Some modern varieties have incorporated specialty traits that may be important for certain growers. Producers that sell hay on a protein-quality basis may realize greater income from varieties bred for higher protein content or quality, although harvest management is usually the greatest factor affecting hay quality. Multifoliate cultivars, those with more than three leaflets per leaf, can have a higher leaf-to-stem ratio, which improves forage quality; however, multifoliate types do not necessarily have higher quality or yield. Many genetic and environmental factors affect both yield and quality. Basing variety selection on any single trait, such as multifoliate habit, would be a mistake.

Growers interested in grazing alfalfa should examine some of the new varieties developed specifically for grazing tolerance. Several varieties withstand grazing quite well and also are useful for hay production.

Fall dormancy is a varietal characteristic that helps plants prepare for winter. Varieties differ in fall dormancy and, thus, in their ability to remain productive late in the season. If varieties have too high a fall dormancy level, they go dormant too early, reducing late-August and September yields. In southern Kansas, varieties do not need as high a level of fall dormancy as in northern areas. Generally, in northern Kansas, varieties with a fall dormancy rating of 3 or 4 are selected. In southern Kansas, varieties rated 4 or 5 are typically grown.

Adequate winter hardiness is important for alfalfa varieties in Kansas. Extremely hardy varieties generally demonstrate lower yield potential. Varieties adapted to the northern United States produce lower yields in Kansas because they are slower to resume growth in the spring, recover slowly after cutting, and go dormant early in the fall.

There are three major alfalfa types from which all U.S. varieties are developed.

Common alfalfas (*Medicago sativa ssp. sativa*) are purple-flowered, predominantly upright types that vary in winter hardiness.

Chilean alfalfas (Spanish) trace to imports from Chile. Several regional strains have developed that vary widely in cold tolerance and in fall- and spring-growth habits. The first alfalfa in Kansas originated from this germplasm.

Turkistan alfalfas are representative of those grown in southern Russia, Iran, Afghanistan, and Turkey. They are generally susceptible to leaf and stem diseases but resistant to some insects and crown and root diseases. They vary in winter hardiness from moderately hardy to hardy.

Flemish alfalfas were developed in northern France. They are vigorous and stemmy, recover quickly after cutting, and mature early. They are resistant to certain foliar diseases, susceptible to root and crown diseases, and moderately winter hardy.

Nonhardy alfalfas are grown in the southern United States. They are characterized by a lack of winter hardiness, upright growth habit, quick recovery after cutting, and long periods of growth.

Yellow-flowered alfalfas (*Medicago sativa ssp. falcata*) are of no commercial importance in Kansas, but because they are very cold-resistant, they are of interest for hybridizing with purple-flowered alfalfa to produce hardy varieties. They range in growth habit from prostrate to upright; they are a source of broad crowns, creeping-root habit, and some foliar-disease resistance.

Variegated alfalfas (*Medicago sativa ssp.* × *varia*) resulted from natural crossing between the common and yellow-flowered types. Flower color is variegated and includes purple, brown, green, greenish-yellow, and others. Generally, these alfalfas are more cold-resistant than common alfalfa because of their yellow-flowered ancestry.

Time of Planting

Alfalfa can be planted either in the spring or late summer. Spring plantings can be made after danger of frost. Plantings will begin first in southern and southeastern Kansas. April to mid-May plantings allow establishment without danger of freezing. In southern and eastern areas, earlier plantings occur, especially when seeded with spring oats as a nurse crop.

With irrigation, plantings should be made in April through May but can be made through early June. There is an increased chance of weed competition with spring plantings, and use of preplant-incorporated herbicides may reduce weeds. Establishment-year yields of spring-planted alfalfa are considerably lower than those of late-summer plantings.

Late-summer plantings usually have fewer weeds, but available soil moisture for germination and establishment prior to the killing frost may be limiting. A late-summer planting should be done in mid-August, as moisture and temperature conditions permit. These plantings begin in northwestern areas and should be completed by early or mid-September in southeastern Kansas. This provides adequate time for seedlings to become well established before entering winter dormancy. Plants should have at least three to five trifoliate leaves before dormancy.

Planting Methods

A perfect alfalfa seedbed should be firm to reduce air pockets, fine to obtain an even covering of seed, level with no places where water stands, and free from weeds that compete with seedlings for moisture and plant nutrients. Seedbed preparation is costly, time-consuming, and promotes the loss of valuable soil moisture. It is important to prepare a seedbed in the most efficient manner to reduce establishment costs and moisture loss.

There is increased interest in planting no-till alfalfa into row-crop stubble in the spring and after small grain cereals or in forage sorghum and silage stubble in late summer. Late summer seedings are often after winter wheat or spring oats. Alfalfa can be planted no-till into these residues. Most no-till drills can be used effectively to penetrate the standing stubble to obtain good seed-soil contact.

Combines should be equipped with straw spreaders to avoid windrows. Downed stubble may cause hairpinning when the straw is wet or if the coulters are not sharp. To reduce the amount of straw, it can be baled or burned just prior to planting so most drills can be used.

Planting no-till alfalfa after row crops also can be effective, especially if the crop is harvested for silage and if conditions were dry during harvest so there are no tire tracks. Often, farmers choose to perform some tillage to knock down the ridges and level the field. When considering no-till planting, planning is important for success. Fields that have had residual herbicides applied for the previous crops should be avoided to reduce the chances of carry-over herbicide damage to alfalfa seedlings. A fertility program for alfalfa will have to be implemented prior to planting the no-till alfalfa.

Good seed-soil contact is critical in alfalfa establishment to ensure quick germination. A cultipacker-type seeder or grain drill with press wheels firms the soil, resulting in good contact with the seed.

Some producers reduce the seeding rate by half in conjunction with cross drilling. Planting in one direction is followed by planting at a right angle to the initial seeding. Broadcast seedings followed with a soil packer may result in adequate stands, but this is the least-desirable method. Seeding rates should be increased by one-third when using this method.

Other producers have broadcast the seed with large fertilizer applicators at the same time liquid fertilizer is being applied. The success rate with this practice, as with any broadcast seeding, depends on available surface moisture.

Some producers overseed alfalfa by drilling or broadcasting into winter wheat in early spring. This method is more successful when wheat stands are thin or in late-planted wheat, which has little spring growth. If the wheat is too tall or has thick stands, the seedling alfalfa is unable to compete, resulting in a poor stand.

Some producers are interested in a dormant season planting from December to February. Based on research from southwest Kansas, this is not recommended due to poor stand establishment.

Producers in eastern Kansas regularly use a nurse or companion crop, such as spring oats, when planting alfalfa. The oats are baled early, leaving the alfalfa to make its growth. In drier areas, a nurse or companion crop is seldom recommended. Under stressful conditions, the nurse crop competes with alfalfa seedlings for moisture and nutrients, often resulting in poor stands. Late-fall plantings may require a nurse crop, such as spring oats or millet, to protect seedlings from harsh weather and prevent erosion.

Planting Rates

Planting rates vary across the state and with differing conditions. In western Kansas, 8 to 12 pounds per acre is recommended for nonirrigated seeding rates. On medium- and fine-textured irrigated fields, a planting rate of 10 to 15 pounds per acre is adequate. On irrigated sandy soils, 15 to 20 pounds per acre is recommended. In central and eastern Kansas, the planting rate varies from 8 to 15 pounds per acre, depending on soil types and moisture conditions.

The recommended seeding rates may seem exaggerated when considering there are about 225,000 seeds per pound. A 1-pound-per-acre seeding rate would be equivalent to about five seeds per square foot. Not all seeds germinate and emerge, though, and the recommended rates ensure adequate stands.

After the first growing season, the plant population will be about eight to 10 plants per square foot. The plant population will continue to decline with the age of the stand. After several years, there may be only three to five plants per square foot. Because alfalfa compensates for thinner stands by producing more stems, yields decline gradually. Weeds begin to invade stands with less than two or three plants per square foot, resulting in lower hay yield and quality. Herbicides are available to reduce weed populations. If the alfalfa-plant population is too low, the best option is to mechanically or chemically destroy the stand and rotate to a row crop or reseed to alfalfa. Rather than counting the number of plants per square foot, some researchers suggest that fields with fewer than 50 stems per square foot be replaced.

Always use seed that has been treated with a fungicide. Seedling diseases can have a devastating effect on stand density and uniformity. Diseases will be a greater problem in fields that have had alfalfa previously.

Alfalfa roots need *Rhizobium* bacteria in order to fix nitrogen. Most commercial alfalfa seed is available in a preinoculated form. Seed should be inoculated with commercially available inoculum prior to planting.

Planting Depth

Planting depth is important in determining stand establishment. Small-seeded legumes, like alfalfa, cannot emerge from deep plantings. Planting depths may vary with soil types. On sandy soils, the seed should not be placed deeper than 0.5 to 0.75 inch, whereas on medium- or fine-textured soils, 0.25 to 0.5 inch is adequate. A guideline for alfalfa is the planting depth should be no more than 10 times the diameter of the seed.

Stand Renovation

Overseeding to thicken an old stand is generally unsuccessful because alfalfa plants produce a toxic compound that kills alfalfa seedlings. The exception would be newly seeded stands with large unestablished areas in which the seedbed can be prepared before planting. Cultivating with a disc, harrow, or other tillage implement to thicken old stands is not recommended. Damage to the crown often results in further stand deterioration.

Producing Alfalfa Seed

Seed production is of secondary importance to Kansas alfalfa growers. Alfalfa is grown primarily for hay and left for seed production only if weather conditions are appropriate.

Production practices are the same for hay and seed, but in seed production, row widths of 20 to 40 inches are used. Adequate phosphorus is important for satisfactory seed production. Phosphate fertilizer should be applied according to soil-test recommendations. The seed crop should receive only enough water to promote moderate top growth until blooming. Moisture conditions that promote slow-growing, vigorous plants provide root reserves for seed production.

At blooming, additional water will lengthen the blooming period, but excessive water will promote vegetative growth and lower seed yields. Avoid sprinkle irrigation while the alfalfa is in bloom because it damages the flowers and interferes with pollination.

In most years, the second cutting is best suited for seed production. The first cutting is usually light in bloom due to cooler weather and shorter day length. Pollinating insects are not as active earlier in the season, and as a result, seed yields are lower. The third and fourth cuttings are often too late for good seed set and maturation.

The ideal time to have alfalfa come into bloom for high seed yield is July. The first cutting should be delayed to one-half or three-fourths bloom to increase root reserves and allow the second cutting to bloom and mature during the warm conditions of July and August. It takes about 30 days from the time a flower is pollinated and fertilized until the seed is mature.

Blooming will continue for about 3 weeks, which stretches seed maturity over several weeks. Higher yields will be obtained if the whole seed crop is allowed to mature before harvest. This is seldom achieved in Kansas due to the weather. Therefore, producers harvest when three-fourths of the pods are black or brown.

The alfalfa flower must be tripped to set seed. This is done best by pollinating insects, primarily wild bees and honeybees. No practical mechanical means of pollinating alfalfa have been developed. Seed set can be improved in the following manners:

- Protecting nesting places of wild bees.
- Increasing the honeybee population. Three to six hives of honeybees per acre, distributed evenly in the field, are recommended for good seed production.
- Controlling flowering weeds and competitive crops that may attract bees away from the alfalfa during the flowering period.

Direct combining from windrows is a common method of harvesting alfalfa seed. Careful attention must be given to proper adjustment of the combine to prevent excessive seed losses.

- Adjust the concave and shelling-plate clearance and speed to thresh alfalfa.
- Regulate ground speed to keep the machine evenly loaded.
- Properly adjust volume and direction of air to prevent seed from blowing over while keeping the sieves from loading up with excessive chaff and hulls.
- Use properly sized sieves to allow all alfalfa seed to pass.
- Adjust chaffer to allow seed and pods to fall. The seed will pass through the sieves, and the pods will go to the return elevator for rethreshing.

Alfalfa Fertility

Lime and Fertilizer Needs

Alfalfa responds well to liming and fertilization with phosphorus and potassium. Because alfalfa is a forage crop normally harvested three to five times a growing season with the above-ground portion of the plant harvested, nutrient removal is high. Table 1 shows the nutrient removal for alfalfa.

A soil test prior to alfalfa establishment is essential to determine lime and fertilizer needs. Soil tests should be taken well before seeding to allow time for incorporation of lime and fertilizer into the soil. Once alfalfa is established, there is no opportunity to incorporate lime.

Lime

Alfalfa does not tolerate low soil pH as well as wheat or grain sorghum. Alfalfa grows best at a soil pH of 6.5 to 7.5. A pH in this range not only promotes good overall growth but also is essential for healthy functioning of the *Rhizobium* bacteria that fix atmospheric nitrogen for subsequent use by the alfalfa.

When soil tests indicate a less-than-optimum pH, lime should be applied according to recommendations and thoroughly incorporated prior to seeding. Lime recommendations are made in pounds of effective calcium carbonate (ECC) to bring the soil to a pH of 6.8 at a 6- to 7-inch depth.

In central and western Kansas, subsoil pH also should be taken into account as many of these soils are neutral to alkaline just below the surface. Liming is recommended in those areas where the subsoil also shows a need for lime.

Table 1. *Nutrient Removal by Alfalfa (Pounds of Nutrient per Ton of Alfalfa)*

N *	55.0
P_2O_5	10.0
K_2O	60.0
Ca	30.0
Mg	4.6
S	8.0
Zn	0.06
Cu	0.14
Mn	1.8
Fe	1.8
B	0.02

* Properly inoculated and nodulated alfalfa gets nitrogen from the air.

Nitrogen

Rhizobium bacteria, present on well-nodulated alfalfa, can fix enough nitrogen to meet the needs of the growing alfalfa crop. Until nodulation occurs, however, alfalfa seedlings depend on available soil nitrogen for growth. A preplant application of 15 to 20 pounds of nitrogen per acre is recommended to get alfalfa started on many fields. A profile nitrogen soil test prior to seeding will help identify nitrogen needs. If sufficient residual nitrogen is present in the soil, additional nitrogen is not needed.

Inoculation of alfalfa seed is recommended, even though fields with prior alfalfa history may have sufficient *Rhizobium* bacteria for effective nodulation. Use fresh inoculant and the proper species of *Rhizobium* for alfalfa. For proper mixing and handling, follow label directions on the inoculum bag.

With good nodulation and actively functioning nitrogen-fixing *Rhizobium* bacteria, there is no need for supplemental applications of nitrogen fertilizer. Effective nodules are generally elongated and have pink to reddish-brown centers, while ineffective nodules are small and rounded with white to pale-green centers.

Nitrogen fertilizer applied to well-nodulated alfalfa will only stimulate grassy and broadleaf weeds and may reduce stand longevity.

Phosphorus

Soil testing is essential for determining phosphorus-application rates. Table 2 shows suggested phosphate rates for new seeding and established alfalfa under irrigated and nonirrigated conditions at various soil-test levels.

Phosphorus for new seedings may be broadcast and thoroughly incorporated prior to planting. If the seeding equipment has fertilizer attachments, phosphorus may be banded at seeding. If a mixed-grade fertilizer such as 18-46-0 or 8-32-16 is used, no more than 10 pounds per acre of nitrogen plus potash should be placed in direct seed contact.

On established stands, broadcasting phosphorus has proven effective on soils low in phosphorus because alfalfa has roots near the soil surface. For nonirrigated stands, top dressing is normally done in the fall, early spring, or even after the first cutting. Irrigated stands can be fertilized in the fall, early spring, or after any cutting because moisture can be supplied to make the top-dressed fertilizer available to plants.

Little difference exists between liquids or solids, or ortho- or polyphosphates, as phosphorus sources for alfalfa. Use of straight phosphate sources (0-46-0) over ammonium phosphate is preferred for top dressing to minimize weed competition, but availability of straight phosphates is limited, and the use of ammonium phosphates (18-46-0, 10-34-0) as phosphorus sources for alfalfa has been successful.

Potassium

Potassium removal in alfalfa forage is quite high when compared with grain crops (Table 1). Many Kansas soils have good levels of potassium. Soil testing is essential in determining potassium need and rate of application.

Recommended rates of potassium application are shown in Table 3. Application times and methods are similar to those for phosphorus, and in most cases, the nutrients will be applied together.

Potash can cause salt injury to new seedlings, and any banded starter fertilizer placed in direct seed contact should contain no more than 10 pounds of nitrogen plus potash per acre. Potassium-fertilizer sources are considered equal for supplying potassium.

Secondary and Micronutrients

The secondary nutrient sulfur and the micronutrient boron are of most concern on alfalfa in Kansas. Limited research does not support the use of other secondary and micronutrients.

Alfalfa is generally considered more responsive to sulfur than other common agronomic crops. Soil testing to determine sulfur and organic-matter levels is needed to make a sulfur recommendation.

Sulfur should be applied based on this equation:

S_{rec} = (YG × 6) – SOM – SH_2O – SMan – SST,
where YG = yield goal, SOM = sulfur in organic matter (2.5 pounds of sulfur per 1 percent organic matter), SH_2O = sulfur in irrigation water, and SST = soil-test sulfur.

Example: Irrigated alfalfa
Yield goal = 8 tons per acre
Irrigation data: 15 inches water applied, containing 2 parts per million sulfur

Table 2. *Phosphorus Recommendations for Alfalfa*

Condition	Area of state	Very low 0-5	Low 6-12	Medium 13-25	High 26-50	Very high >50
		Soil test for phosphorous (ppm)				
		pounds per acre of P_2O_5				
New seeding						
Irrigated	Entire	90-120	70-90	50-70	0-50	None
Nonirrigated	Eastern	80-100	60-80	40-60	0-40	None
	Western	60-80	40-60	20-40	0-20	None
Established stand						
Irrigated	Entire	90-110	60-90	40-60	0-40	None
Nonirrigated	Eastern	60-80	40-60	30-40	0-30	None
	Western	40-60	30-40	0-30	None	None

Table 3. *Potassium Recommendations for Alfalfa*

Condition	Area of state	Very low 0-40	Low 41-80	Medium 81-120	High 121-160	Very high >160
		Soil test for potassium (ppm)				
		pounds per acre of K_2O				
New seeding						
Irrigated	Entire	100-140	80-100	50-80	0-50	None
Nonirrigated	Entire	100-120	70-100	40-70	0-40	None
Established stand						
Irrigated	Entire	100-120	70-100	50-70	0-50	None
Nonirrigated	Entire	90-120	60-90	40-60	0-40	None

Soil-test sulfur = 2 parts per million in top 2 feet of soil
Soil organic matter = 1 percent
S_{rec} = (8 × 6) – 2.5 – 10.2 – 0 – 14.4 = 21 pounds/acre

Ideally, a sampling depth of 2 feet is recommended because sulfur is mobile in the soil.

Areas most likely to respond to sulfur are sandy soils low in organic matter with low cation-exchange capacity. In many irrigated areas, the irrigation water may supply sufficient sulfur for optimum growth. Adequate levels of sulfur are essential for optimum forage quality.

Boron deficiency on alfalfa has been recognized for many years in southeastern Kansas. Typically, symptoms will occur on the second cutting in dry periods following a good first cutting. Symptoms will appear as spotty yellowing on newer leaves and shortened upper internodes. Boron availability is associated with the organic matter, and dry-surface soils reduce boron uptake.

A broadcast application of a boron-supplying material will be effective in correcting any deficiency. In most cases, an application of 1 to 4 pounds of boron per acre will be sufficient. Boron should not be overapplied as there is potential for boron toxicity.

Weed Management

Weeds interfere with alfalfa production by reducing plant stands, forage quality, and yields. Alfalfa seedlings are not competitive with weeds, and heavy weed pressure in newly seeded alfalfa often chokes out alfalfa seedlings, causing thin stands. Good alfalfa-stand establishment reduces future weed competition and enhances the crop's life and productivity. Vigorous alfalfa stands are very competitive with weeds and, with proper management, may reduce populations of certain weeds such as common milkweed, hemp dogbane, Johnsongrass, and shattercane. A successful weed-management program begins before alfalfa is seeded and continues throughout the life of the stand.

Weed and Herbicide Management before Planting

Establishing a vigorous stand of alfalfa is essential for a productive crop, and weed and herbicide management can influence stand establishment. It is important to know the history of the cropping system, weed problems, and herbicide use prior to seeding a new stand of alfalfa.

Several herbicides can carry over from the previous crop and injure alfalfa seedlings. Atrazine, Authority, Glean, Amber, Ally, Canopy, Finesse, Peak, and Tordon are examples of herbicides that can carry over a year or more, especially on high-pH soils, and injure new alfalfa seedings.

Weeds must be controlled before alfalfa is seeded. Weeds often are controlled prior to planting with tillage operations for seedbed preparation. Tillage can effectively control annual weeds but does not provide long-term control of perennial weeds. Several herbicides can be used prior to planting alfalfa for weed control in reduced-tillage systems or for perennial-weed control.

Roundup and Gramoxone Extra are nonselective herbicides that can be applied for control of existing vegetation any time before alfalfa seedling emergence. Gramoxone Extra is a contact herbicide that requires thorough spray coverage and is most effective for control of small annual weeds. Roundup is a systemic herbicide that is translocated into the roots. It is more effective than Gramoxone Extra for long-term suppression of perennial weeds. Gramoxone Extra tends to be more effective on broadleaves than grasses, while Roundup tends to be more effective on grasses than broadleaves. Both herbicides require proper use of adjuvants—agents added to enhance their effectiveness—and application techniques to achieve good weed control.

Weeds and Weed Management in Seedling Alfalfa

Cultural practices that promote rapid, uniform emergence and growth of newly seeded alfalfa will give alfalfa a competitive advantage over weeds. A well-prepared seedbed, optimum soil fertility and pH, good quality alfalfa seed that does not contain weed seeds, proper seeding rates and dates, and favorable weather conditions favor successful alfalfa establishment. The type of weed problems encountered in newly seeded alfalfa will depend on cropping history and seeding time.

Summer annual weeds such as foxtails, crabgrass, lambsquarters, and pigweeds are the primary weed problems with spring-seeded alfalfa. These are fast-growing weeds that can reduce alfalfa stands, especially if dry weather is encountered during the first summer.

Weed competition usually is not as serious with fall-seeded alfalfa; however, winter annual weeds such askbit, field pennycress, tansy mustard, cheatgrass, and volunteer wheat can be problems in fall-seeded alfalfa, especially following wheat.

Eptam, Balan, Treflan, Buctril, Butyrac, Poast Plus, Pursuit, and Select herbicides can be used for weed control in seedling alfalfa. Eptam, Balan, and Treflan must be preplant-incorporated. These herbicides provide several weeks of control of many summer annual grasses and some summer annual broadleaves, but they are not effective for control of most winter annual weeds. Eptam, Balan, and Treflan can cause early-season stunting and stand reductions, especially with deep seeding and cool, wet conditions during emergence.

Butyrac and Buctril can be used early-postemergence on seedling alfalfa for control of small broadleaf weeds. Buctril can be applied to seedling alfalfa after the four-trifoliolate stage for control of seedling weeds less than 2 inches in diameter or 2 inches tall. Buctril can provide good control of many seedling broadleaf weeds but is less effective on larger weeds or winter annual weeds that have overwintered.

Buctril application can result in unacceptable crop injury when temperatures exceed 80 degrees Fahrenheit in western Kansas or 70 degrees Fahrenheit in eastern Kansas at or within 3 days after treatment. Do not feed or graze spring-treated alfalfa within 30 days of fall-treated alfalfa or within 60 days following Buctril application.

Butyrac can be applied to established or seedling alfalfa after the two-trifoliolate stage for control of emerged, susceptible broadleaves that are less than 3 inches in diameter or 3 inches tall. Alfalfa should not be grazed or harvested for 60 days following Butyrac application.

Pursuit can be used postemergence in seedling or established alfalfa for annual broadleaf and grass control. It can be applied after alfalfa is in the two-trifoliolate stage for control of small, actively growing weeds. Pursuit provides some residual weed control in addition to foliar activity. Always apply with a nonionic surfactant or oil concentrate plus nitrogen-fertilizer solutions.

Pursuit provides good control of many summer annual weeds, such as foxtails, shattercane, velvetleaf, and cocklebur. It also may provide good control of kochia and pigweeds, unless resistant populations are present. Many winter annual broadleaf weeds are susceptible to Pursuit, but cheatgrass and volunteer wheat are only partially controlled. Pursuit generally is more effective on winter annual weeds as a fall treatment than a spring treatment. Do not feed, harvest, or allow grazing of alfalfa for 30 days following Pursuit application.

Poast Plus and Select are systemic grass-control herbicides that can be used in seedling or established alfalfa for annual and perennial grass control. Poast Plus and Select can control many annual grasses in alfalfa, including foxtails, crabgrass, and volunteer cereals. Always apply in combination with a crop-oil concentrate at rates suggested on the label.

Select is labeled for control of cheatgrasses, while Poast Plus is not. Volunteer cereals and cheatgrass that have overwintered or grasses that have been mowed are more tolerant to Poast Plus or Select treatment. Allow several days of regrowth and use higher application rates of Poast Plus or Select for control of grasses that have been mowed. Do not graze, feed, or cut undried forage for 7 days or harvest treated hay for 20 days following Poast Plus application. Do not apply Select within 15 days of grazing, feeding, or harvesting alfalfa for forage or hay.

Weed Management in Established Alfalfa

Weeds generally are not a serious problem the first few years after successful establishment of a well-fertilized, insect-free alfalfa stand. As the alfalfa stand ages, the population often thins, and weeds begin to invade open areas. Both summer and winter annual weeds can be a problem in established alfalfa, depending on management, alfalfa stands, and growing conditions.

Dormant-season tillage can provide control of winter annual weeds in established alfalfa but also may damage alfalfa crowns and predispose plants to diseases. Tillage of established alfalfa has been discouraged in higher-rainfall areas due to the increased risk of diseases but has been used successfully in western Kansas without apparent detrimental effects.

Irrigation timing can be used to manage summer annual weeds in established alfalfa. Research and experience with irrigated alfalfa at the Sandyland Experiment Field near St. John indicate an irrigation approximately 5 days before cutting and again 5 or 6 days after cutting promotes rapid regrowth of alfalfa without stimulating annual-grass germination and growth.

Several herbicides are available to control weeds in established alfalfa. The decision to use a herbicide in established alfalfa should be based on the type and level of weed infestations, alfalfa-quality needs, and alfalfa-stand density. Use of herbicides may help improve the quality of a thin, weedy stand of alfalfa but will not help rejuvenate the crop.

Herbicides used in established alfalfa can be divided into two groups, depending on application timing. Postemergence herbicide treatments are applied during the alfalfa growing season, and dormant-season treatments are applied during the winter when the alfalfa is not actively growing.

Butyrac, Pursuit, Poast Plus, and Select can be used postemergence in established alfalfa as described previously in the seedling alfalfa section. In addition, Gramoxone Extra can be used postemergence between alfalfa cuttings or as a dormant-season treatment. Gramoxone Extra is a nonselective contact herbicide, so all actively growing plant tissue will be destroyed, but alfalfa crowns and roots will not be adversely affected.

Because most of the alfalfa foliage is removed during harvest, treatment soon after cutting or when alfalfa is dormant has little or no effect on alfalfa's health and productivity. Any regrowth that has occurred prior to application will be destroyed by the treatment. Gramoxone Extra controls emerged weeds only and will not provide residual weed control. Do not cut, graze, or harvest alfalfa for 30 days following between-cutting treatments or for 60 days following dormant-season applications of Gramoxone Extra.

Other dormant-season treatments—including Karmex, Lexone, Sencor, Sinbar, and Velpar—can control existing winter annual weeds, such as cheatgrass and mustards, and provide some residual weed control. Residual activity depends on the herbicide, rate of application, and precipitation.

Karmex, Velpar, and Sinbar generally provide more residual control than Sencor or Lexone. These treatments can be applied to established alfalfa any time after it ceases growth in the fall until it resumes active growth in the spring.

Dormant-season treatments applied after regrowth occurs in the spring may cause unacceptable crop injury. Precipitation within 2 weeks of application is essential for good weed control. The activity of these herbicides is influenced by soil pH and texture; therefore, rates must be adjusted accordingly. Rotation to other crops is restricted for up to 2 years after application of Karmex, Sinbar, and Velpar and up to 1 year following Sencor or Lexone.

Treflan and Zorial can be used as a dormant-season or between-cutting treatment for preemergence control of annual grasses such as foxtails, crabgrass, and barnyardgrass and some small-seeded broadleaf weeds like pigweed. These herbicides provide residual weed control but will not control emerged weeds. Treflan can be applied in irrigation water or as a broadcast treatment. Zorial should be broadcast.

Approximately 1 inch of precipitation or irrigation is required for herbicide activation. An irrigation or rainfall is needed within 3 days following a broadcast Treflan application, or the herbicide must be mechanically incorporated into the soil. Do not cut or graze alfalfa for 21 days following Treflan application or 28 days following Zorial application.

Eptam also can be applied in irrigation water to established alfalfa to provide preemergence control of annual grasses and some broadleaf weeds. Eptam will not control emerged weeds. Do not apply Eptam to alfalfa within 14 days of harvest or grazing.

The relative effectiveness of herbicides labeled for use on alfalfa at the time of publication is presented in Table 4. Read and follow all directions, warnings, and precautions on the label before applying any pesticide. For additional information on herbicide use in alfalfa, refer to the Annual Report of Progress, *Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland*, available at any K-State Research and Extension county office.

Table 4. Weed and Crop Response to Selected Alfalfa Herbicides When Applied According to Label Directions [1]

Herbicide(s)	Alfalfa Tolerance	Cheatgrass	V. Cereals	Prickly Lettuce	Tansy Mustard	Treacle Mustard	F. Pennycress	Shepherdspurse	Henbit	Barnyardgrass	Crabgrass	Foxtail	F. Sandbur	Kochia	Lambsquarters	Pigweeds	Common Ragweed	P. Smartweed
		Winter annuals								Summer annuals								
		Grasses		Broadleaves						Grasses				Broadleaves				
Preplant:																		
Balan	G	F	P	N	N	N	N	N	N	E	E	E	E	F	F-G	F-G	N	N
Eptam	F-G	FG	P	N	N	P	N	F	F	E	E	E	E	F	F-G	F-G	F	P
Treflan	F-G	FG	P	N	N	N	N	N	P	E	E	E	E	F	F-G	F-G	N	N
Postemergence to alfalfa & preemergence to weeds:																		
Eptam	F-G	FG	P	N	N	P	N	F	F	E	E	E	E	F	G	F-G	F	P
Treflan	FE	G	F	N	N	N	N	N	N	E	E	E	GE	F-G	G	G-E	N	N
Zorial	G	G	G		G	G	F-G	G	-	G	E	E	F-G	F	F	FG	F	F
Postemergence:																		
Buctril	G	N	N	F-G	G	G	G-E	GE	G	N	N	N	N	G	G-E	F-G	G	G-E
Butyrac 200	FG	N	N	G	G	G	G	G	F	N	N	N	N	F-G	G-E	G-E	G	G-E
Gramoxone Extra	F	F-G	FG	G	N	N	N	N	N	G	G	G	G	F	G	G	G	G
Poast Plus	E	G	G	N	N	N	N	N	N	E	G	E	E	N	N	N	N	N
Pursuit	G-E	F	P	P	GE	G-E	G-E	G-E	G	F-G	F-G	GE	F	G[2]	P	G[2]	P	G
Select	E	G-E	G-E	N	N	N	N	N	N	E	G	E	E	N	N	N	N	N
Dormant treatments:																		
Gramoxone Extra	E	F	F	G	F	G	G	G	G	N	N	N	N	N	N	N	N	N
Karmex	G	FG	F	E	E	E	E	E	P	G-E	G-E	GE	F	G	E	E	G-E	F-G
Lexone/Sencor	G	GE	F	G	E	E	E	E	GE	F	F	F	P	E	E	G	E	GE
Sinbar	G	G	F	E	E	E	E	E	GE	G	G	G	G	GE	E	G	E	E
Velpar	G	G	F	F	E	E	E	E	G	G	F	G	F	F	G	G	G	F-G

[1] Weed response ratings refer to application according to label directions and with favorable growing conditions: E = Excellent; G = Good; F = Fair; P = Poor; and N = None.
[2] Except where resistant weed populations have developed.

Irrigating Alfalfa

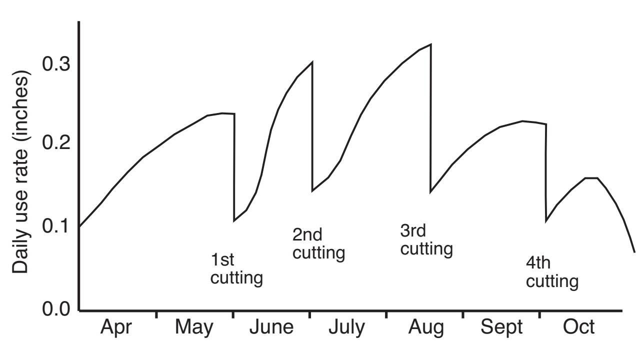
Alfalfa is a deep-rooted, drought-tolerant perennial with a long growing season. As a consequence, it also is a large water user with seasonal water use in excess of 40 inches. In deep, well-aerated soil, roots may extend 8 to 12 feet deep. Alfalfa grows from early spring until late fall or early winter. Growth begins when the average temperature reaches 50 degrees Fahrenheit and continues until a killing freeze occurs. When soil water is sufficient, alfalfa grows in direct relation to the temperature and sunlight available.

Water-use Characteristics

Alfalfa requires more water than any other Kansas crop. The net irrigation requirement varies from 14 inches in Linn County on the eastern border to 27 inches in Morton County in southwest Kansas. The average seasonal water need for alfalfa is about 4 acre-inches per ton of production. During the summer months, the water use is 6 to 7 acre-inches per ton. Alfalfa is drought-tolerant, using up to 70 percent of available soil water without undue stress or loss of production; if stressed beyond this limit, it will merely stop growing until soil water is available. There are limits, but plants recover from extremely dry periods. Production suffers, but the crop survives. Alfalfa can be a good crop for irrigators with limited water supplies.

A normal water-use curve for alfalfa with four cuttings is shown in Figure 1. Removing the leaf area

Figure 1. *Normal Water-use Pattern of Alfalfa*



causes an abrupt drop in the use rate. As regrowth occurs, the use rate increases rapidly toward that of a mature plant. A normal use rate for midseason is 0.35 inch per day, or about an inch of water every 3 days.

Peak rates of 0.5 inch per day, however, are not uncommon. Peak rates seldom last more than a day or two, but rates in excess of 0.35 inch per day have been recorded for several weeks. With its deep root system, alfalfa can continue to grow through such periods if there is enough soil-water storage. The combination of soil-water storage and irrigation-system capacity must equal the long-term use rates if production is to be maintained.

Alfalfa is sensitive to excess soil water or the lack of good aeration. Surface water should not be allowed to stand more than 24 hours during hot weather or 48 hours during lower temperatures.

A deep, medium- to coarse-textured soil with adequate water is ideal. Fine-textured soils are usually difficult to manage. Excess moisture is conducive to development of root and crown diseases. Shallow water tables limit root growth.

Alfalfa does not have a critical stage of growth, as do many other crops. The seedling stage is sensitive to soil water because seeds are small and the reserves of energy and moisture also are small. The period of regrowth after cutting is sensitive, but that is due to encouraging weed competition from surface water if it is applied immediately after cutting. Irrigation is therefore not advised. A dry surface with adequate water below the top 12 to 18 inches gives alfalfa an advantage over shallow-rooted grasses and weeds.

Irrigation Management

Only the top 3 to 4 feet of the root zone are considered when irrigating alfalfa. Water below this depth is used, but roots remove water where it is most abundant in the root zone. The upper half of the root zone contains more than half the roots, and about 80 percent of the water will come from this area. Research has shown if water is readily available to at least half the roots, plants experience little or no stress. As a consequence, if water is available in the upper half of the root zone, little will be used in the lower half.

Limited irrigation exploits the deeper soil water by not fully watering the upper root zone. Production is not as great, but more soil water storage is available for precipitation and a greater production per unit of irrigation water is obtained. Whether or not this is an economical scheme is site-specific. Cost of pumping, crop value, and all costs associated with the irrigation system and management must be considered. With a limited water supply, early- and late-season irrigations can be used because of alfalfa's long growing season and deep root zone.

Scheduling

An irrigation schedule should be developed for any irrigated crop. Scheduling is a cost-effective procedure an irrigator can institute to improve irrigation management. The checkbook method is recommended because of the flexibility it allows in determining when and how much to irrigate. An initial estimate or measurement of root-zone soil water is needed. This usually requires installing soil-water-measuring equipment or soil probing.

Table 5 describes the visual "hand feel" method. This is the simplest procedure and, with experience, is generally adequate for irrigation management. The irrigator may install soil-water-sensor blocks at various depths and field locations and determine soil water with a portable electric meter. These are good for medium- to fine-textured soils. On sandy soils, a tensiometer may be used. These are easier to read but lack the range to cover the soil-water-availability status of all soils. These, however, provide adequate information for most scheduling.

Checkbook Method

The amount of soil water initially found is considered as money in the bank. Crop water-use estimates are treated as withdrawals, and irrigation and rainfall amount to deposits. A running balance is maintained daily or at short intervals so soil-water storage is known at all times. Crop-use-rate values, or "ET" (evapotranspiration), can be computed from weather data, selected from tables based on weather information, or in some cases, obtained from local experiment fields or agricultural radio broadcasts.

Several periodic soil-water evaluations are recommended as a check. None of the procedures for securing crop-use rates are precise. Irrigation amounts and rainfall measurements are not exact. This procedure may indicate more or less soil water than is actually present. Carefully done, the procedure should not lead to extreme errors, so a check during each cutting cycle is usually sufficient.

Other Methods

Measuring soil water at frequent intervals is an excellent method. How well it works depends on the

Table 5. *Interpretation Chart for Soil Water*

Soil water remaining	Texture or appearance of soils: Very light	Light	Medium	Heavy and very heavy
0%	Dry, loose, single-grained; flows through fingers.	Dry, loose; flows through fingers.	Powdery, dry; sometimes slightly crusted but easily breaks down into powdery condition.	Hard, baked, cracked; sometimes has loose crumbs on surface.
Less than 50%	Still appears to be dry; will not form a ball with pressure.	Still appears to be dry; will not form a ball. [1]	Somewhat crumbly, but will hold together from pressure.	Somewhat pliable; will ball under pressure. [1]
50% to 75%	Same as very light texture, with less than 50% moisture.	Tends to ball under pressure, but seldom will hold together.	Forms a ball [1], somewhat plastic; will sometimes stick slightly with pressure.	Forms a ball and is very pliable; sticks readily if relatively high in clay.
75% to field capacity	Tends to stick together slightly; sometimes forms a very weak ball under pressure.	Forms weak ball; breaks easily, will not stick.	Forms ball; will ribbon out between thumb and forefinger.	Easily ribbons out between fingers; has a slick feeling.
At field capacity (100%)	Upon squeezing, no free water appears on soil, but wet outline of ball is left on hand.	Same as very light texture.	Same as very light texture.	Same as very light texture.
Greater than field capacity	Free water appears when soil is bounced in hand.	Free water will be released with kneading.	Can squeeze out free water.	Puddles, and free water forms on surface.

[1] Ball is formed by squeezing a handful of soil firmly with fingers.

frequency, number, and location of measurements. It can be an exacting procedure, but doing an exacting job is time-consuming. Soil-water-measuring equipment must be monitored frequently—at least twice a week at midseason—and records of measurements kept to guide irrigation timing.

Calendar-date scheduling is the procedure of applying water based on the time of year. Alfalfa is one crop in Kansas where such scheduling is useful. The deep rooting habit and drought tolerance does not make the irrigation schedule as critical as it is for other crops. In a dry year, production may be lost because the amount of adjustment for timing or amount of irrigation water is not known; in wetter years, water may be wasted for a similar but opposite reason. In well-drained, medium to light soils, the consequences of short-term periods of excess moisture are of no particular concern. The procedure is not as efficient as others.

Finally, scheduling may be done on the basis of crop-stress signs. A careful observer will note a change in the crop's color as soil-water stress develops. Leaves become blue-green. This color occurs before wilting. If the irrigation system is capable of providing water rapidly, these color changes may be used to schedule. It takes several days for the color change to occur, and if water can be provided before wilting occurs, this scheduling will work.

The major difficulty is system capacity. From the time enough color change occurs to alert the irrigator, only a few days remain until the onset of wilting. Few irrigation systems in Kansas have such large capacities they can cover the field before a yield loss occurs. If only color is used, it is difficult to anticipate when irrigation may be needed.

Irrigation Timing

Alfalfa is sensitive to water stress at harvest. Rapid regrowth depends on adequate soil water. Watering prior to harvest or immediately after is the best time to promote rapid growth. Soil compaction may occur if the field is watered before harvesting. A firm, dry surface is best for traffic and field drying. Watering immediately after harvest stimulates growth of existing weeds.

If the irrigation system has limited capacity, as most center pivots do during midseason, there may be little choice. The system will be shut off during cutting and started again when the crop is removed.

Harvest reduces the use rate for a time, which may allow the system to partially catch up with the long-term demand.

The strategy that seems to fit most situations during the growing season is to irrigate a few days to a week before harvest. Allow the surface to dry and stabilize for harvest, then fill the root zone as soon after harvest as conditions allow. Usually, on medium-textured soils, 4 to 6 inches of water between cuttings is sufficient.

Surface Irrigation

Surface systems usually have greater capacity. Corrugations and bedded-furrow irrigation of alfalfa are practiced by many who also surface irrigate other crops, but graded borders are nearly ideal for alfalfa irrigation in Kansas. Border strips are long, relatively narrow areas contained between low dikes along either side.

Border strips are usually a uniform grade of 0.3 to 3 percent along the length but are level across the slope. Water is rapidly introduced along the upper end and flows to the lower end. The alfalfa provides roughness to slow the water, help it spread across the strip, and prevent erosion. Properly designed, there is little runoff, and the application efficiency is 75 to 85 percent. Wind and low humidity have only minor effects, and this system is relatively easy to manage.

Bedded-furrow systems and corrugations are operated in a similar manner, but control is less precise. Corrugations are shallow furrows that help direct water flow in the direction they are formed. They are too shallow to prevent overtopping if the flow is too great and are easily obstructed. Corrugations are a cheap method of gaining some control. Furrows or bedded furrows offer more control of the water through irrigations but present a rougher surface to work at harvest.

Center Pivots

Center pivots may be the most effective method of obtaining good uniformity for the irrigation water when alfalfa is grown on sandy soils, but the low water-holding capacity of sandy soils presents some unforeseen management problems. Center pivots are frequently unable to keep up with the long-term demand. Under such circumstances, the irrigator should be aware of how long the soil-water storage is sufficient to continue normal growth. For example, if a midseason use of 0.35 inch per day continues and the system has a normal application rate of 0.28 inch per day, 0.07 inch per day must be supplied from soil-water storage that will not be replaced by irrigation until the daily-use rate is less than the application rate. This is an excess use of only 1 inch every 14 days. The 0.28 inch per day is an estimate based on an average application efficiency of 80 percent.

When weather conditions cause higher use rates, the application efficiency of sprinkler systems is lower than normal. A quarter-section center pivot covering 130 acres requires 853 gallons per minute to apply 0.28 inch per day at 80-percent efficiency. If the weather caused the efficiency to fall to 70 percent, then only 0.24 inch per day would be applied, and an inch of water in storage would last only 9 days.

Many center pivots lack the capacity to apply 0.28 inch per day even under the best conditions, and soil-water reserves are depleted sooner. Sandy profiles frequently hold only 1 inch per foot; thus, a 4-foot root zone contains only about 4 inches, and 70-percent allowable soil-water depletion is 2.8 inches. If the system were lacking 0.1 inch per day, the soil-water reserves could last 28 days, which would seem adequate. During harvest, as many as 7 days of irrigation may be missed, which further reduces irrigation capacity and causes greater use of soil-water reserves. Without knowing the status of the soil water or the application efficiency of the system, many irrigators get into trouble.

This can occur for any type of irrigation system, and the solution is to reduce the area irrigated. A center pivot can be run on half the field and with double the available water to that portion. The same thing may be done with other irrigation systems. Continuing to irrigate the entire area is a waste of time and resources. Once the plant has wilted and remains that way, production is reduced. Lower plant parts may remain green from inadequate watering, but real growth has stopped. Applying the correct amount of water to a limited area is more profitable. Site-specific economic analysis is needed to determine the optimum acreage to be irrigated with a given water supply.

Some irrigators prefer to check the irrigation application by using a simple steel probe. A simple probe consisting of a steel rod $^5/_{16}$ to $^3/_8$ inch in diameter with a slightly larger ball welded to the end is all that is necessary. A day after irrigation, push the probe into the soil at several locations. Where it penetrates easily, it is wet, and where it meets resistance, it has not been wetted. Allow time for water movement downward for probing to be useful, but too long an interval causes confusion because of continued plant use. The amount of penetration from an irrigation will depend on the water-holding capacity of the soil. Probing may need to be delayed until the second day after irrigation on fine-textured soils in order to get a better measure of the total depth of penetration from the irrigation application.

Subsurface Drip Irrigation (SDI)

The new technology of subsurface drip irrigation (SDI) has some promises for alfalfa irrigation according to studies done in California and Texas. K-State findings for SDI in corn suggest it is a feasible practice for small or odd-shaped fields where center pivots are not feasible. In California studies, the yield difference between 40 and 80 inches of lateral spacings were not appreciable. The increase in depth of placement from 16 to 25 inches in silty-clay soil eliminated wet spots in the surface and helped field operations.

The results in California suggest in a silty-clay soil the spacing of 60 inches with a placement depth of 25 inches is most suitable. In a light-textured soil, the placement depth may be reduced. Germination of alfalfa seeds under SDI will need the help of hand-set sprinkler irrigation or adequate rainfall at planting time. Since an alfalfa stand will stay in production for more than 3 years, it may be economical to rent sprinklers for irrigation during germination. Savings from reduced pumping of water over the years, increase in yield, and improvement of quality may pay for the extra cost of stand establishment.

Additional references are available from the K-State Irrigation Management Series: L914, *Using Evapotranspiration Reports for Furrow Irrigation Scheduling*; L915, *Using Evapotranspiration Reports for Center Pivot Irrigation Scheduling*; L795, *Soil Water Measurements: An Aid to Irrigation Water Management*; L901, *Scheduling Irrigations by Electrical Resistance Blocks*; and L796, *Tensiometer Use in Scheduling Irrigation*.

Managing Alfalfa Insects

Many insects are present in every Kansas alfalfa field, but most are of no consequence to producers. Many are even beneficial. The 13 species or groups described in this section sometimes require additional attention to minimize economic losses caused when dense populations feed on alfalfa foliage. Modified harvest dates, resistant varieties, and insecticides are not mentioned in this publication. For that information refer to MF809, *Alfalfa Insect Management*. Copies of this publication are available from K-State Research and Extension county offices and through our web pages (*http://www.ksre.ksu.edu/bookstore/pubs/MF809.pdf*).

When insecticides are warranted, close attention should be given to choosing and applying the products best-suited for the situation. Observe differences in rates and mandatory preharvest intervals to prevent illegal pesticide residues. Use adequate gallonage. In ground equipment, 10 to 12 gallons of water per acre may be sufficient if the alfalfa is less than 7 inches tall. On 8- to 15-inch alfalfa, 15 to 20 gallons should be used. At least 20 gallons per acre should be used in dense growth and where the alfalfa is greater than 15 inches tall. Control with aerial applications has sometimes been frustrating, probably in part because of the low gallonage applied. Use the highest practical gallonage. For example, 4 gallons is probably superior to 2 gallons when insecticides are applied by airplane. Be sure the boom height on ground equipment is adjusted to eliminate over-treated and untreated areas.

Army Cutworm

Pale greenish-gray to brown caterpillars with the back pale-striped and finely splotched with white and brown but without prominent markings cause damage in March, April, and May in the western two-thirds of the state. Seedling fields suffer the most permanent damage. The stand is easily thinned because young plants have few carbohydrate reserves or secondary buds from which new shoots can develop. Treat with recommended insecticides when two or more larvae per square foot are present in seedling fields or four or more per square foot are found in established fields.

Clover Leaf Weevil

Damage may occur March through early May. Like the alfalfa weevil, the larvae are green with a white dorsal stripe. Clover leaf weevil larvae, however, have a brown head capsule, whereas alfalfa weevil larvae have black head capsules. Clover leaf weevil larvae are approximately ½ inch long at maturity and may have a faint pink line near the white dorsal stripe. Grubs frequently turn yellow and die because a pathogenic fungus has infected them, keeping the population under control. Insecticides may be justified if five or more healthy grubs are found per crown.

Alfalfa Weevil

The 3⁄16-inch-long adult has mouthparts at the end of a snout. Overall adult color is light brown with a middorsal dark line. Eggs are laid inside alfalfa stems in the fall or spring. They hatch in the spring into small, light-green, black-headed worms or larvae that are legless and have a white stripe down the center of the body.

Damage typically occurs during the first cutting; however, both larvae and adults can suppress yields by delaying regrowth. The larvae feed for about 3 weeks and become slightly more than ¼ inch long at maturity. Most damage is confined to terminal and other upper leaves. As feeding continues and increases, the drying, tattered foliage gives fields a gray, frosted appearance.

Some studies have indicated protein content and digestibility of the hay may be lowered significantly. If infestations are heavy enough, all foliage may be destroyed. Severe damage to the first cutting may result in indirect losses through delayed growth and reduced production in several later cuttings. Individual plants or all plants in heavily attacked areas, especially under windrows, may die.

Chemical and nonchemical management becomes very important. Several tiny parasitic wasps and at least one fungal disease help suppress weevil-population buildup in Kansas. Varieties with some tolerance to weevil attack are available, but dramatic levels of resistance capable of halting heavy infestations are not expected for some time.

Several scouting tips have been developed to assist producers in decision making. Control measures should not be delayed on 3- to 7-inch-tall alfalfa when larvae are numerous and the top inch of growth is showing some feeding damage unless loss of the top growth from a late frost is expected. Two treatments spaced approximately 2 weeks apart may be necessary. Control measures should be applied to 8- to 14-inch-tall alfalfa if larvae are numerous and skeletonizing the top 1 to 2 inches of growth on about 30 to 50 percent of the terminal. If the top 2 to 3 inches are being injured on the majority of plants and the alfalfa is within 2 weeks of cutting, it may be advisable to cut early if the hay can be removed from the field rapidly and bright, hot conditions follow to limit larvae survival. Otherwise, spraying would be advisable, especially if harvest must be delayed for several days.

The previous guidelines should be used in conjunction with the alfalfa weevil stem-count decision chart (Figure 2) To decide if an alfalfa field should be treated for alfalfa weevil, it is recommended the stem-count decision method be used: carefully break off 30 to 50 stems, selected at random from across the field, and shake them individually into a deep-sided bucket. Count the stems, determine the average stem height, count the larvae, and determine the average number of larvae per stem. Refer to the alfalfa weevil stem-count decision guide to determine the suggested management action.

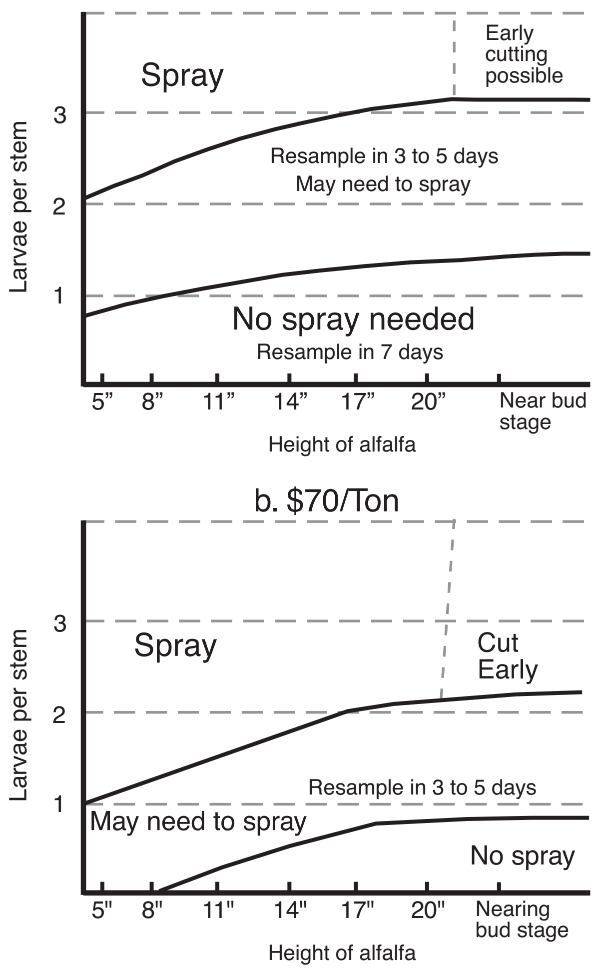
The first relationship was developed for situations where alfalfa was selling for $35 per ton. As the alfalfa value increases, fewer larvae are required to reach a treatment threshold. For instance, Figure 2b indicates $70 per ton of alfalfa should be treated at just more than two larvae per stem when the alfalfa is approximately 17 inches tall vs. requiring nearly three larvae per stem to trigger treatment when the crop is valued at $35 per ton. As the price climbs further, even fewer alfalfa-weevil larvae may be needed to trigger treatment.

A stubble-time spray may be necessary to suppress large numbers of larvae destroying newly developing buds and foliage. Eight or more larvae per square foot in stubble will delay green-up enough to warrant treatment. If less than four larvae are found, treatments are seldom required. Adult weevils also may prevent regrowth and require treatment under unusual conditions.

Pea Aphids and Blue Alfalfa Aphids

Large green aphids (measuring up to 3⁄16 long by 1⁄16 inch wide) feeding on the alfalfa stems are most often identified as pea aphids. However, there is a similar insect known as the blue alfalfa aphid which also occasionally becomes a pest in Kansas. The pea aphid has dark blue bands around the base of its antennal segments, whereas the blue alfalfa aphid lacks these basal antennal bands. Alfalfa varieties vary in their resistance to these two aphids, so

Figure 2. *Alfalfa Weevil Stem-count Method*



growers should consider pest species and past infestation history, plus local adaptability of the cultivar, when selecting among varieties. Recently, there have been reports indicating that some populations of pea aphids may be evolving to where they can damage some formerly aphid resistant varieties. Thus, growers need to be alert for high populations or signs of damage, even when planting resistant varieties. Evaluating relative plant vigor is the key to determining the need for treatment.

Very light populations of pea aphids may be beneficial by providing a food source for beneficial insects. Heavily infested plants may turn yellow and wilt. Treatment is justified if aphid populations cause wilting. Approximately 50 aphids per stem on 10-inch-tall alfalfa (100 pea aphids per stem on 20-inch-tall alfalfa) require treatment, especially if plants are starting to wilt and cutting is 1 to 2 weeks away. Under good growing conditions, much higher numbers may be tolerated.

For blue alfalfa aphids, 20 per stem on 10-inch alfalfa (50 per stem on 20-inch alfalfa) may be all that is necessary to justify treatment. Keep fields under close surveillance early in the season during periods of slow growth. Early cutting may destroy heavy aphid populations.

Variegated Cutworms

This climbing, foliage-feeding cutworm has four or five white dots, one per segment, down the center of the back. If variegated cutworms are noticed before cutting, are abundant but not stripping the foliage from the standing crop, and most are nearing pupation (1½ inch long and about the diameter of the average wooden pencil), it may be advisable to delay cutting a few days. This should allow the majority of larvae to pupate, thereby avoiding the more serious problem that develops when cutting forces immature larvae to repetitively remove the regrowth.

Another regrowth problem occurs when hungry larvae concentrate below windrows so that relatively sparse populations fieldwide may cause serious damage to that area, especially if windrow removal is delayed. Chemical controls are recommended when more than two or three worms per square foot are present after the first cutting.

Blister Beetles

These are large, soft-shelled, usually slow-moving beetles with swollen bodies. Although blossoms and leaves in localized areas may be devoured by concentrations of beetles, fieldwide sprays to prevent further foliar damage are seldom warranted.

Instead, the greatest concern results when the swarming species are crushed during hay making and become embedded in baled hay. Horses exhibit an adverse and sometimes fatal reaction when fed hay containing crushed blister beetles. Avoiding the use of the mid-June through September cuttings for horse feed may be advisable. Using natural drying or a self-propelled swather (mower-windrower combination) with crimper rollers removed so unconditioned hay is delivered into a windrow straddled by the unit’s wide-set wheels may reduce the risk of serious blister-beetle infestation. Avoid feeding hay to horses from the turn areas where the tires pass directly over the mown hay.

Sidecut sicklebar mowers can kill a number of blister beetles when the tires pass over the fallen hay as the tractor makes the next trip around the field. Therefore, sicklebar mowers will not guarantee delivery of blister-beetle-free hay. Use of insecticides may be unwise because this traps the toxin in the field, rather than letting the beetles transport it elsewhere. (See publication MF959, *Blister Beetles in Alfalfa*, for more information).

Grasshoppers

Damage may be caused from May until frost by these robust, jumping insects that chew the foliage. Control of nymphs is much easier to achieve than control of adults. Young stands less than 6 inches tall or the post-cutting regrowth of established stands need to be protected. Repeated applications may be required because labeled insecticides have short residual properties. Field margins probably should be treated when densities reach 20 to 60 small nymphs or 12 to 21 large nymphs or adults per square yard. Five to eight large nymphs or adults per square yard are required to justify treatment of standing alfalfa.

Webworms

Larvae are slender, greenish-black, spotted caterpillars. On the side of each segment at maturity are three dark spots, each of which possesses one to three bristle-like hairs. A light stripe also runs down the middle of the back. Early cutting often eliminates midseason infestations. Insecticide should be used if the crop is more than 2 weeks from cutting and 25 to 30 percent of the terminals are becoming webbed. On seedling alfalfa, treat if two or three worms per square foot are observed.

Potato Leafhopper

These are ⅛-inch-long, yellow-green, wedge-shaped insects that move rapidly sideways, jump, or fly. Injured plants typically exhibit V-shaped yellowing of the leaf tips (hopperburn). Stunted, yellowed plants are less valuable for livestock feed because of reduced protein levels. Controls should be applied before yellowing begins. Stunted alfalfa should be harvested to remove eggs. One spray applied to the stubble is usually adequate.

Treatment is recommended when one-fifth, one-half, one, and two leafhoppers per sweep are noted on alfalfa 3 inches or shorter, 6 inches tall, 8 to 10 inches tall, and 12 to 14 inches tall, respectively. These treatment thresholds are based on the average count per sweep from 20 pendulum sweeps per location across five locations.

Alfalfa Caterpillar

The larvae are green worms with a white stripe along each side of their bodies, a velvety skin surface, and reach 1¼ to 1½ inch in length at maturity. Damaging populations are most likely to occur late in the summer in southwest Kansas fields that remain 5 or more weeks between cuttings. Control measures are justified when 10 worms are collected per sweep.

Fall Armyworms

Caterpillars are up to 1½ inch long with four dark spots arranged at the corners of an imaginary square at the rear and usually have an inverted "Y" on the front of the head. Infestations are most likely to occur from late summer through early fall, before frost (September and October). One or two worms per square foot may destroy seedling alfalfa and 10 to 15 per square foot have destroyed 12- to 14-inch alfalfa.

Spotted Alfalfa Aphids

These 1⁄16-inch-long, greenish-yellow to straw-colored aphids have faint rows of dark spots on the back. This aphid is typically found on the underside of leaves and is favored by hot, dry conditions. Insecticides should be applied when two or three aphids per seedling are present and temperatures exceed 65 degrees Fahrenheit.

One aphid may cause serious damage to a seedling plant while it may take 50 aphids per plant to damage 10" tall, well-established alfalfa. Resistant varieties are available and may be essential for successful stand establishment in years when spotted alfalfa aphids are abundant.

Disease Management

Alfalfa diseases can cause substantial losses of both yield and quality. Seedling diseases may hinder stand establishment. Wilt diseases reduce stand density and yields. Leaf and stem diseases cause premature leaf loss and thus reduce forage feed value. Root and crown rots weaken plants and are a major limiting factor in stand persistence.

Disease management in alfalfa begins with field selection. Poorly drained fields favor development of seedling damping-off, Phytophthora root rot, and

Aphanomyces root rot. Crop rotation helps reduce soilborne inoculum of several diseases including Verticillium wilt.

Varietal resistance is the most important method of disease control in alfalfa. Good resistance is available for the three wilts, Phytophthora root rot, Aphanomyces root rot, anthracnose, and stem nematode. Disease ratings can be found in the most recent alfalfa performance test bulletin, which is available at county K-State Research & Extension offices.

Seed treatment with metalaxyl protects seedlings against *Pythium* and *Phytophthora*. Timely cutting can help avert defoliation by leaf spot diseases. Proper fertility, timely irrigation, insect control, and proper cutting schedules can greatly reduce problems with root and crown rot.

The following table summarizes the diseases, pathogens, symptoms, and recommended controls for alfalfa diseases in Kansas. Help with diagnosing and managing alfalfa diseases is available through your local county K-State Research and Extension office.

Disease and Pathogen	**Symptoms**	**Recommended Controls**	**Comments**
Bacterial wilt *Clavibacter michiganense* subsp. *insidiosum*	Entire plant stunted; leaves yellowish green, sometimes wilted; cross sections of taproots show a ring of light yellowish brown discoloration; plants eventually die.	Resistant varieties. Crop rotation.	Most varieties now very resistant. Survives in crop debris.
Fusarium wilt *Fusarium oxysporum* f.sp. *medicaginis*	Scattered stems or entire plant with yellow, wilted, or dead leaves; cross sections of taproots show a ring of dark reddish brown discoloration; plants eventually die.	Resistant varieties.	Survives in debris and the soil for many years.
Verticillium wilt *Verticillium albo-atrum*	Scattered stems or entire plant with yellow, wilted, or dead leaves; often with "v" shaped yellow or tan leaf tips; cross sections of taproots show a ring of light brown discoloration; plants eventually die.	Resistant varieties. Crop rotation for 2 to 3 years with good broadleaf weed control. Avoid transport of debris from infested fields to clean fields.	Survives in alfalfa seed, crop debris and in some weeds.
Phytophthora root rot *Phytophthora megasperma* f.sp. *medicaginis*	Plants may be stunted or wilted; leaves yellow or reddish purple; large tan, brown, or black lesions on roots, taproot often rotted several inches below soil surface where impervious layer holds water.	Resistant varieties. Avoid poorly drained sites. Avoid excess irrigation. Use metalaxyl seed treatment.	Favored by waterlogged soil. Survives in soil for many years. Plants may grow new roots if environmental conditions improve.
Aphanomyces root rot *Aphanomyces euteiches*	Seedlings have yellow cotyledons, roots grayish to brown; older plants have reduced lateral roots.	Resistant varieties. Avoid poorly drained sites. Avoid excess irrigation.	Favored by waterlogged soil. Metalaxyl not effective. Importance in Kansas unknown.

Crown and root rot complex *Fusarium* spp. and *Rhizoctonia solani*	Crowns and/or roots have reddish, yellowish, brown, or black rotted areas; taproot often hollow; plants stunted; leaves yellow, wilted, or dead.	Proper cutting schedule. Proper fertility. Control insects. Don' t cultivate established stands. Crop rotation may delay, but not prevent, development of crown and root rot.	Any type of stress that reduces carbohydrate reserves promotes root and crown rot. The pathogens survive in soil for many years.
Damping-off *Pythium* spp., *Phytophthora megasperma* and *Rhizoctonia solani*	Seedlings fail to emerge or die soon after emergence.	Avoid poorly drained sites. Avoid excess irrigation during establishment. Use metalaxyl seed treatment. Use Phytophthora resistant variety. Use higher seeding rate in problem fields.	Favored by waterlogged soil. Survives in soil for many years.
Anthracnose *Colletotrichum trifolii*	Individual wilted or dead shoots have light tan lesions with brown borders on lower stems that contain numerous small black fruiting bodies.	Resistant varieties.	May also cause crown rot characterized by blue-black discoloration.
Spring blackstem *Phoma medicaginis*	Numerous small (1/16 inch) brownish-black leaf spots; also produces variable-sized black stem lesions.	Cut early if leaf loss is excessive.	Favored by cool, moist weather. Very common. May also cause crown rot.
Summer blackstem *Cercospora medicaginis*	Circular leaf spots up to 1/4 inch are brown, later becoming silvery brown; also produces variable sized black stem lesions.	Cut early if leaf loss is excessive.	Favored by warm, humid weather. Very common.
Lepto leaf spot *Leptosphaerulina briosiana*	Small (1/16 inch) brown leaf spots with dark brown border and usually a yellow halo.	Cut early if leaf loss is excessive.	Favored by cool, wet weather. Common.
Yellow leaf blotch *Leptotrochila medicaginis*	Yellow, elongated blotches parallel to the leaf veins contain numerous dark brown specks.	Cut early if leaf loss is excessive.	Favored by cool, moist weather.

Common leaf spot *Pseudopeziza medicaginis*	Brown, circular leaf spots 1/16 inch in diameter contain one dark brown, raised, disk-shaped fungal fruiting body in center.	Cut early if leaf loss is excessive.	Favored by cool, moist weather. Despite name, not the most common leaf disease.
Downy mildew *Peronospora trifoliorum*	Upper leaf surface has light yellowish green blotches; lower leaf surface has light gray patches of downy fungal growth.	Cut early if leaf loss is excessive. Use metalaxyl seed treatment for fall seeding.	Favored by cool, moist weather.
Rust *Uromyces striatus*	Small pustules (1/32 inch) on leaves with dusty, brownish-orange spores.	Timely cutting.	Builds up when third or fourth cutting is delayed.
Bacterial leaf spot *Xanthomonas campestris pv. alfalfae*	Irregularly shaped water-soaked leaf lesions later become translucent tan; seedlings stunted; may cause black stem lesions.	None.	More common in fall seedings where it can cause significant stand losses.
Alfalfa mosaic Alfalfa mosaic virus	Yellow or light green mosaic pattern on leaves; systemic infection.	None.	Symptoms most distinct during cool weather.
Stem nematode *Ditylenchus dipsaci*	Patches of plants stunted; leaves distorted, often pale; nodes swollen; internodes shortened; buds proliferate excessively.	Resistant varieties.	Favored by cool, moist weather. Reported from southern Kansas.

Cutting Management and Forage Quality

Stage of maturity at harvest affects alfalfa forage yield, quality, and stand persistence. Alfalfa has the potential to produce substantial tonnage of quality forage, high in protein and carotene and low in fiber. Obtaining the highest season-long forage yields, however, requires cutting at late-maturity stages. Cutting at early-maturity stages maximizes quality. In either case, stand persistence can be adversely affected, thus shortening stand life.

For example, research has shown continually cutting at the bud stage produces lower yields and fewer pounds of protein per acre than cutting at the one-tenth bloom stage. The stand also is thinned and overtaken by weeds with continual bud-stage cutting. A balance between forage yield and quality is necessary in order to preserve the stand. The exception is the dairy producer who demands high-quality forage with less concern for quantity and stand longevity. In this case, the characteristic high-percentage crude protein, protein digestibility, and carotene content of alfalfa harvested at the pre-bud and bud stages are the priority.

With established stands, three indicators determine when alfalfa should be cut: crown regrowth, one-tenth bloom, or prior to extreme leaf loss. In the spring, alfalfa flowering is delayed because of the shorter photoperiod. With accumulated aboveground growth, however, nutrients are translocated to roots to replenish carbohydrate reserves. Crown regrowth is initiated in response to replenished root reserves (see the illustration on the inside back cover). This regrowth will be the second cutting. If first cutting is delayed to one-tenth bloom or later, the advanced regrowth will be removed with the first cutting, delaying the next hay crop. First cutting should be based on crown regrowth and subsequent cuttings on one-tenth bloom, which generally coincides with crown regrowth. This growth stage is the compromise for optimizing both forage yield and quality, yet maintaining stand longevity. One goal of alfalfa producers is to make two cuttings before wheat harvest, if weather permits.

Situations may arise that cause premature leaf loss and require cutting before crown regrowth or one-tenth bloom. These include lodging, insect and disease damage, and drought. Green leaves contain the majority of nutrients compared to stems, thus leaf retention is essential to produce high-quality forage. If cutting is required before the recommended stage, root reserves may not be fully recovered to permit rapid regrowth; yet left uncut, the hay crop will deteriorate, and stand vigor may decline.

Cutting at an increased stubble height will aid in conserving root reserves. Although yields may be affected slightly, this practice will enhance axillary-bud regrowth along with crown regrowth, which will reduce demands on weakened plants. After salvaging this cutting, the next cutting must be delayed slightly to ensure replenishment of carbohydrate reserves.

Cutting management of newly established stands is slightly different compared to older stands. The first cutting on new stands should be delayed from one-tenth to one-half bloom to ensure replenishment of root reserves for rapid regrowth. Typically, the regrowth under this delayed initial cutting is not significant enough in height to be removed with the first harvest. Subsequent cuts can be made at one-tenth bloom or when crown regrowth appears.

The last fall cutting may influence the alfalfa stand's performance the following year. If root reserves are not replenished before the fall killing freeze (20 to 25 degrees Fahrenheit) or initiation of dormancy, the stand is more susceptible to winter damage, resulting in slower initial spring growth. Final fall cuttings should be based on crown regrowth rather than one-tenth bloom because of the decreasing photoperiod.

The last cutting, prior to fall dormancy, should be made so there are 8 to 12 inches of foliage or 4 to 6 weeks of growth time before the average killing freeze date. This allows adequate time for replenishment of root reserves. For northern areas of the state, the third week of September should be the target date for the last cutting before dormancy, and the first week of October is the cutoff date for southeastern Kansas.

Many producers are tempted to harvest the forage in mid-October if significant growth has occurred. Cutting during this time will initiate regrowth, which reduces root reserves during a critical time. If the producer does not harvest during this critical period, the remaining forage can be hayed safely or grazed after the killing freeze. This fall management decision depends on the overall management plan of the producer and the environmental conditions for harvesting.

Alfalfa forage quality is based on two components: protein and fiber. The protein is calculated as percent crude protein. The fiber is divided into two groups: acid detergent fiber (ADF) and neutral detergent fiber (NDF). An estimate of the energy value of the feedstuff, which includes both ADF and NDF in its calculation, is the relative feed-value (RFV) index.

The crude-protein estimate includes both the true protein and the nonprotein nitrogen fractions. It is calculated by first measuring the total nitrogen, then multiplying by 6.25. A percent-crude-protein figure is then used to determine the capacity of the forage to meet the animal's protein requirement. Typically, alfalfa harvested at early maturity stages or with a high percentage of leaves will result in a relatively high crude-protein forage (Table 7).

Acid detergent fiber is the percentage of highly indigestible and slowly digestible components of a forage. These include cellulose, lignin, pectin, and ash. This fraction is indicative of forage digestibility with lower values—such as 30 percent ADF—being more desirable.

Neutral detergent fiber is the percentage of fiber in a forage. It consists of the acid detergent fiber components minus the pectin plus hemicellulose. This fraction is inversely related to animal consumption; the higher the NDF percentage, the lower the intake. Like acid detergent fiber, lower NDF values—such as 40 percent—are more desirable.

Relative feed value is an index used to compare similar forages (Table 7). This popular calculation uses the digestible dry matter intake of full-bloom alfalfa as the basis for relative comparisons (RFV = 100). First, the digestible dry matter (DDM) of alfalfa is calculated on a percent-dry-matter basis: DDM = 88.9 – (0.779 × ADF). Next, the dry matter intake (DMI) of alfalfa is calculated on a percent-bodyweight basis: DMI = 120 ÷ NDF. Relative feed value is then calculated by using the following equation: RFV = (DDM × DMI) ÷ 1.29.

Considering the quality components, cutting time becomes a method of controlling alfalfa forage quality. Alfalfa cut at the late-bud to one-tenth-bloom stages can have 20 to 25 percent crude-protein levels. Delaying harvest until full bloom to increase dry-matter yields results in hay crude-protein levels of 10 to 15 percent, with lower relative feed values and carotene content. Research has shown alfalfa cut at one-tenth bloom for more than 6 years yielded a significantly greater tonnage of both dry matter and crude protein compared with forage alternately cut at the bud and full-bloom stages.

Leaves, compared with stems, are essential to obtain high-quality alfalfa forage. Approximately two-thirds of the crude protein and more than half of the carotene in alfalfa hay is in the leaves. Conversely, three-fourths of the less-digestible fiber (ADF) in alfalfa hay is present in the stems. Forage-fiber content increases as harvest is delayed and plants mature. It is critical to limit leaf damage in unharvested alfalfa and leaf loss during harvest to preserve the high quality potential of alfalfa forage.

Table 7. *Height, Percent Crude Protein, and Percent Relative Feed Value of Alfalfa at Different First-cutting Stages*

Maturity stage	Height (inches)	Crude protein (percent)	RFV (percent)
Vegetative	16	26	153
Early-bud	20	23	134
Late-bud	22	21	132
First-regrowth	25	20	117
25%-bloom	27	17	111
50%-bloom	30	15	107
Full-bloom	31	14	103
Green-seedpod	31	14	98

K-State, 1992

Harvest Equipment and Storage

When selecting a hay harvesting-storage-feeding system, the following questions must be considered:

- What are the costs associated with the system?
- What are quality considerations?
- Is the harvesting system compatible with present and future equipment, facilities, and operations?

Labor has been a major factor in the adoption of various hay-harvesting systems. More labor is needed for small square bales when they are handled manually than for any other system. Bale accumulators and automatic bale wagons reduce labor requirements. Increased labor requirements increase production costs, but the cost of the entire system should be considered when making a decision.

Other harvesting costs to consider are associated with owning and operating equipment. Oklahoma State University has developed computer software called HAYMACH$ for evaluating hay-production-equipment costs. This software was used to compare the costs of owning and operating a self-propelled (SP) swather, pull-type (PT) swather,

Figure 3. Cost Comparison of Mowing Systems

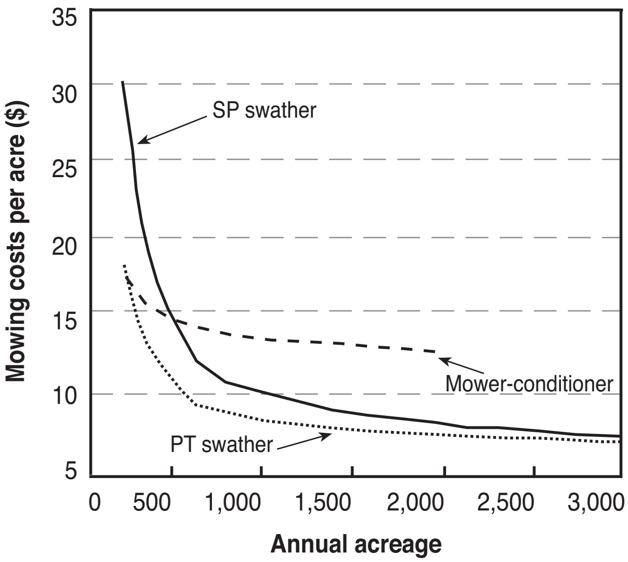
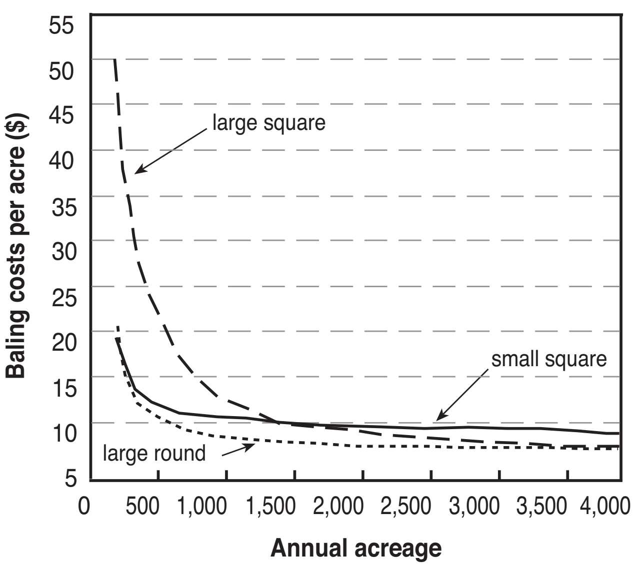


Figure 4. Cost Comparison of Baling Systems



and side-pull mower-conditioner (Figure 3). The costs presented include implement, tractor if needed, and labor costs for each mowing system and are for comparison only. Actual costs may vary substantially from those listed.

Annual acreage is the amount of land on which the implement is used each year. If 200 acres of alfalfa are cut four times each year, the annual acreage is 800 (4 × 200). For all systems, the cost initially decreases with increased annual acreage then approaches a nearly constant value.

The side-pull mower-conditioner has the least cost if less than 200 acres are harvested annually. The pull-type swather is the most economical choice when more than 200 acres are harvested annually. The self-propelled-swather costs approach those of the pull-type swather but are never lower. One explanation for this is that both machines are assumed to have the same field efficiencies, which is probably not true. Increasing the field efficiency of the self-propelled swather would reduce the costs associated with this machine.

A similar comparison of baling equipment is shown in Figure 4. The costs presented include baler, tractor, labor, and twine for each system. The small square baler appears to be the best choice if less than 200 acres are harvested annually. At this point, the large round baler becomes more economical. The extremely high costs associated with the large square baler on low acreage are due to the higher purchase price of the tractor and baler. The large square baler becomes more economical than the small square baler at 1,500 annual acres and approaches the large round baler at about 3,000 annual acres.

Storage

Storage losses occur even under barn conditions and cannot be eliminated. Losses are greatest during unprotected, outside storage of large round bales. Storage losses can be divided into two categories: dry-matter loss and reductions in palatability and digestibility. Dry-matter loss is simply a reduction in bale weight. It does not include any reduction in moisture content due to additional drying. It includes hay lost from the bale during handling and any hay lost to rodents.

Reduced palatability and digestibility usually are caused by weather but can be caused by high-moisture content at baling. Weathered hay may not be as appealing to livestock as unweathered hay. Feeding losses will increase due to the undesired hay being wasted. Even if livestock consume the weathered hay, they mat not be getting any feed value from it. If digestibility is lower, rate of gain also may be lower.

Storage method has a tremendous effect on weathering losses. Barn-stored hay suffers significantly less weathering loss than unprotected hay stored outside. Dry-matter losses for barn-stored hay are generally in the 2- to 8-percent range. Because of their shape, large round bales are not well suited for barn storage. A hay barn simply will not hold as much hay in large round bales as in square bales. Almost 60 percent of Kansas forage and livestock producers recently surveyed said they store all large round bales outside without any type of protection.

Storing Bales Outside

Large round bale storage losses can exceed 25 percent when bales are stored outside without protection in Kansas, but losses can be minimized through good management. Due to lower annual rainfall, western and north central Kansas are better suited for outside storage than south central and eastern Kansas. If outside storage is chosen, close attention should be paid to selecting a storage site and stacking method.

Choosing a Storage Site

A well-drained site minimizes deterioration on the bottom of the bales. Bales stored on damp soil will absorb moisture and deteriorate. Bales should be elevated by stacking them on old tires, shipping pallets, or railroad ties. Adding a base layer of 3 to 4 inches of crushed rock to the storage site will help minimize losses on bale bottoms. Weeds or tall grass at the storage site will increase deterioration of bale bottoms.

Round bales stored outside need air circulation and sunlight to help dry the outer layer after rain. Storing the bales under trees blocks wind circulation and sunlight, which help dry the bales. Any protection the trees might offer is more than offset by the damage due to the shading they cause.

Choosing a Stacking Method

Tightly stacking bales end-to-end minimizes storage area and protects the ends of bales from weathering. If bales are not stacked tightly against each other, rain can penetrate the ends, which increases damage. If bales cannot be stacked tightly end-to-end, an 18-inch space should be left between bales for air circulation. Stacking bales with the rounded sides touching is not recommended. This creates a trap for rain and snow.

Aligning rows north to south allows an equal amount of sunlight on both sides of the bale row, which results in uniform drying. Leaving at least 3 feet between rows allows air to circulate and sunlight to reach the bales. The distance between rows reduces the chance of snow accumulation on the bales. If snow accumulation is a possibility, stack the rows farther apart. The greater distance allows sunlight to melt the snow sooner and reduces weathering losses from the snow.

K-State studies indicate stacking method is not as important as once thought. Three stacking methods—north-south rows, east-west rows, and bales turned on end with another stacked on top—were compared, and all resulted in similar dry-matter and quality losses associated with weathering. Stacking bales in pyramids is a good way to make the most of limited storage space, but weathering losses can be extremely high if bales are not covered.

Bale Wrapping

Net or mesh wrapping is a popular alternative to twine for tying large round bales, and one of the perceived advantages is improved protection from weather. K-State studies found net-wrapped bales did not retain quality better than twine-wrapped bales. Research at the University of Missouri and Michigan State University showed similar results. Some research indicates net is a superior wrapping material on low-density bales.

Solid plastic wrapping also is available for large round bales. It can be applied with the baler or as a separate operation. While the plastic will shed rain, it also traps moisture in the bale. Bales wrapped with plastic should be stored individually if the moisture content at baling exceeds 18 percent. Researchers in Canada and Louisiana found moisture accumulated in the bottom of plastic-wrapped bales stored end-to-end.

Covering Bales

Covering bales offers some promise for reducing weather-related losses for outside storage. Covering bales does have drawbacks. First, if a low-quality cover is used, it may be difficult to keep it on the bale. Wind damage can be devastating for plastic tarps. Any tears must be repaired immediately if the cover is to remain in place. Covers also need to be anchored to the ground or stacked to keep them in place. Reinforced plastic sheeting is more expensive but will probably require less maintenance and last longer.

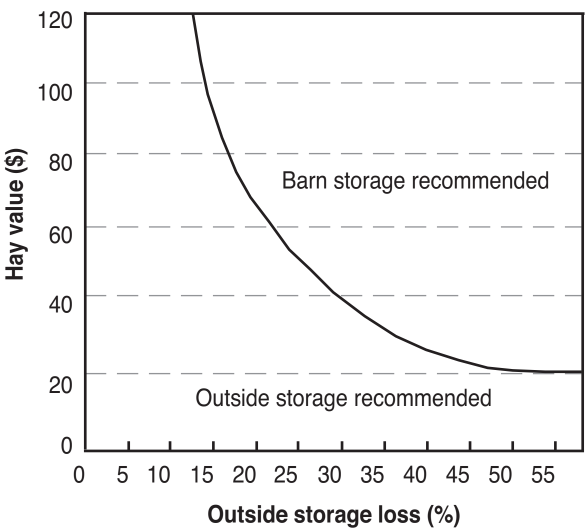
Covering bales with plastic will trap moisture the same as wrapping them in plastic. If high-moisture hay—more than 18 percent—is sealed under plastic, quality losses can result from excessive heating and mold. Condensation at the top of the stack could cause spoilage in high-moisture hay. Stacking covered bales in pyramids minimizes covering costs.

Barn Storage

Barn storage is the best method for preserving hay quality but can be expensive if building a structure is necessary. A typical pole barn with 16 feet of clearance requires about 13 square feet of floor space for each ton of hay stored. With an initial construction cost of $4 per square foot, the cost of building a structure is slightly more than $50 per ton of storage capacity. Depreciation, interest, taxes, insurance, and maintenance can be estimated to have an annual cost of 20 percent of the original cost. This results in an annual ownership cost of about $10 per ton of storage capacity.

Building a barn for hay storage in southwestern Kansas is probably not economical unless hay is sold at premium prices. In eastern Kansas, building a barn for large-round-bale storage is probably economical. Figure 5 shows the relationship between outside storage loss and hay value. If the value of hay lost is typically greater than storage costs, a barn should be considered.

Figure 5. *Hay Value and Outside Storage Loss Determine the Need for Barn Storage*



Feeding

The possibility of hay waste appears to be greater when feeding large hay packages than when feeding small bales, primarily because big packages are more commonly fed without racks. One study showed 13 percent of hay was wasted when fed without racks, while less than 5 percent was lost when feeding with racks. The hay saved with a feed rack will likely pay for the rack in its first or second year of use.

Chemical Aids to Haymaking

Drying and curing high-moisture alfalfa is often the greatest limitation in production of high-quality hay. Alfalfa typically contains as much as 75 to 80 percent moisture at cutting, whereas the hay should have 15 to 18 percent moisture or less for safe storage. The time required for drying alfalfa hay may vary from a few hours, when forage yield is low and it is hot and dry, to several days if the crop is quite heavy and weather is cool or humid.

Dry-matter-yield and quality losses in hay are related to the length of field-curing time. The longer the hay is in the field, the more likely it is to be rained on, further slowing the haymaking process and often causing substantial dry-matter and nutrient losses. Extended curing time contributes to a relatively greater loss of leaves than of stems, decreasing the crude protein and digestible-energy content of the hay and increasing the fiber content.

Techniques developed to hasten drying are use of machines (conditioners) to crush or crimp the stems, use of drying agents or desiccants, and use of chemicals or machines to disrupt the waxy layer (cuticle) on leaves and stems. These techniques allow stems to dry at a rate similar to leaves, improving leaf retention and hay quality and allowing moisture to escape the plant more readily.

While conditioners are widely used in alfalfa haymaking throughout the United States, equipment to disrupt the cuticle has only recently been developed for on-farm use, and desiccants have gained only limited acceptance. Use of desiccants appears most advantageous in cooler, more-humid regions with high rainfall probabilities during the haymaking period.

Another approach to reduce field-curing time and improve hay quality is to harvest and store alfalfa at higher moisture levels, commonly 20 to 30 percent. Preservatives are available that allow storage of high-moisture hay without heating and molding.

Drying Agents

Drying agents are chemical solutions applied to the standing alfalfa crop at the time of cutting. These solutions also are commonly referred to as desiccants or chemical conditioning agents. They reduce field-curing time by substantially increasing the rate at which cut alfalfa plants dry. Drying agents increase the rate of moisture loss from a cut plant. Apparently they act to disrupt the waxy layer on the plant stem, thus reducing the resistance to water loss.

Most available commercial products contain potassium carbonate (K_2CO_3) or sodium carbonate ($NaCO_3$) plus a surfactant or wetting agent to aid in the spreading of the product over the plant surface. Research has shown potassium carbonate to be more effective than the sodium salt; however, sodium carbonate is less expensive and is generally added to reduce product cost.

Many commercial drying agents containing additional components—such as methyl ester of fatty acids, oils, and fats—are available, but these have not been shown to improve drying rates over products containing potassium carbonate alone. Other products containing sodium-silicates and alkaline carbonates have been tested and also appear to be effective.

Drying agents are most effective when applied to the entire alfalfa plant as it is being mowed. Typically, spray equipment is mounted on the mower-conditioner. A push bar mounted ahead of the spray boom is recommended to bend the plants forward so the spray solution can be uniformly applied to the stems and leaves.

Using a roller conditioner with intermeshing rubber rollers is recommended as the rollers seem to help distribute the solution evenly over the entire plant. Recommended application rates vary but are typically in the range of 4 to 7 pounds of potassium carbonate per acre in 30 to 50 gallons of water. The large amount of water is required to ensure adequate and uniform coverage.

Research with drying agents indicates their effect is greatest on second and later cuttings of alfalfa and during times with good drying conditions—low humidity and high temperatures. They are most effective when the crop is laid in a wide, thin swath during mowing. Heavy, thick swaths inhibit moisture dissipation into the surrounding air, lessening the effect of the desiccant. Drying agents are less effective on first cuttings of alfalfa when the climate conditions are typically less favorable for hay drying and yields are high. They also are less effective on grass-alfalfa mixtures compared with pure alfalfa. Although drying agents promote faster drying, it is important to note they have no preservative action and will not allow safe storage of hay with a moisture content greater than 20 percent.

Preservatives

Chemical preservatives are available that allow producers to bale and safely store hay with moisture contents greater than 20 percent. Most commercially available products contain propionic acid or mixtures of propionic and acetic acids. Research has shown propionic acid to be more effective than acetic acid. Both of these organic acids act as fungicides. They work to inhibit both the plant and microbial aerobic activity responsible for heating and molding that occurs in high-moisture hay.

Preservatives are applied at the time of hay packaging and must be uniformly applied to all forage to prevent pockets that can heat and mold within the bale or stack. Recommended rates of propionic acid are 10 pounds per ton (0.5 percent) for hay baled at 20- to 25-percent moisture, 20 pounds per ton (1 percent) at 25- to 30-percent moisture, and 30 pounds per ton (1.5 percent) for hay baled at 30- to 35-percent moisture. Prevention of mold and cost of preservation becomes great when hay contains more than 30 percent moisture. Preservative application is not required for hay with moisture content less than 20 percent.

Propionic acid must be handled and applied with caution. It is highly volatile, irritating to eyes and skin, and corrosive to haymaking equipment. Buffered propionic acid products such as ammonium propionate are available, are less volatile and corrosive, and are relatively safer to apply.

Anhydrous ammonia (NH_3) has been used successfully as a preservative, particularly for low-quality forages such as crop residues or mature grass hays. Application of about 3 percent anhydrous ammonia per ton of dry hay prevents mold growth and raises crude protein content of these low-quality roughages.

Since alfalfa regularly has a high protein content, ammoniation is less beneficial than for low-quality forages. Ammoniation of higher-quality forages has been reported to occasionally produce a toxin (imidazole compounds) that can cause hyperexcitability or even death of livestock. For these reasons, ammoniation of alfalfa hay is not recommended.

A number of companies are promoting and marketing microbial inoculants for use in preserving high-moisture hay. These products contain lactic-acid-producing bacteria—*Lactobacillus* or *Streptococcus*. In addition, some may contain protease or amylase enzymes. Most of these products were originally designed to improve the fermentation of wilted silages, not the preservation of moist hay. Presently, there is no published research demonstrating the effectiveness of microbial inoculants on high-moisture hay.

Summary on Chemicals

Several chemical products are available with the potential to improve alfalfa-hay quality by hastening the drying rate or preventing heating and molding when baled at higher moisture contents. Drying agents (carbonates) accelerate drying, particularly during the first day after cutting. Application of preservatives (organic acids) allows packaging of hay at higher moisture contents without heating or mold formation. Weather conditions during haymaking, cost of materials, and relative need to produce high-quality alfalfa hay determine whether use of these products will be economically advantageous.

Grazing Management

With high yields of quality forage, alfalfa is a versatile crop that can fit economically into several types of forage-production systems. For example, the use of alfalfa as a source of pasture is often overlooked, especially when favorable prices exist between stocker calves and feeder calves. Producers also may harvest the first two cuttings and graze the third when yields may not justify harvest costs. Intensive grazing management is required to maximize alfalfa production while minimizing incidence of bloat. Potentially high cash returns per acre can exist through higher stocking rates coupled with high animal performance. Under ideal grazing situations, production of up to 1,800 pounds of beef per acre has been observed.

A rotational grazing system should be used to maximize life of the stand and obtain efficient use of the alfalfa. The pasture should be divided into at least six equal-sized paddocks and stocked according to the quality and amount of forage available. Under optimum growing conditions in Kansas, alfalfa capable of producing 6 tons of hay per acre can support approximately five or six 400-pound calves per acre. Vegetation should be grazed to no less than 4 inches high within a 5-day period before rotation.

At the onset of the grazing period, approximately half of the pasture should be harvested to prevent overmaturation and subsequent spot-grazing. Use of several paddocks should allow, at the least, a 30-day rest period for each grazing cell before being grazed again. Overgrazing, along with insufficient rest, will accelerate the decline of alfalfa production in future years. During periods of inclement weather, availability of a nearby grassy area is ideal for avoiding excessive trampling of alfalfa crowns.

The coordination of proper stocking rate with ideal grazing time is essential for minimizing the occurrence of bloat. Generally, grazing alfalfa before the one-tenth bloom stage is not recommended as the potential for bloat is high. Initial placement or rotation to new grazing cells should be done mid-morning after livestock have ample opportunity to consume dry roughage, such as grass hay.

Once on pasture, it is important to be consistent and ensure animals never get hungry. To ensure this does not occur, have grass hay available at all times and use its consumption as a barometer of pasture conditions. If grass hay consumption rapidly increases, it is likely alfalfa forage intake is decreasing. In this case, overeating may occur when calves are rotated to fresh pasture, thereby increasing the likelihood of bloat.

While the incidence of bloat is less likely to occur when alfalfa is mature (full bloom) or frosted, attentive management is important to ensure early identification of bloat-provocative situations as they arise. To assist management, commercially available feed additives can be used to minimize bloat. Although expensive at 25 to 30 cents per head per day, Poloxalene—available in mineral block, granular, or liquid form—can effectively minimize the occurrence of bloat, providing animals consistently consume 1 to 2 grams per 100 pounds of body weight daily. Assurance of proper consumption can be achieved by eliminating other salt or mineral products; providing adequate mineral blocks; one block per five head of calves or 25 head of sheep; and providing adequate liquid tank or bunk space if using liquid or granular forms, respectively.

Although not as effective as Poloxalene, ionophores such as Rumensin or Bovatec can minimize the incidence of bloat by 30 to 60 percent. In addition, feeding at the rate of 150 to 200 milligrams per head per day also can improve animal gain by up to 0.2 pound per day. Rumensin and Bovatec are not approved in combination with Poloxalene.

Expected gain of calves on alfalfa pasture can range from 0.65 to 2 pounds per day depending on forage maturity and availability. Considering the level of gain the producer has projected into budgets, additional energy supplementation may be necessary when cattle are grazing dormant or mature alfalfa. For example, depending on the size of the calves and with gain of 1.5 to 1.75 pounds per day, 400- to 600-pound calves may require 2.25 to 4 pounds of grain per day to achieve projected weight gain.

Profit Prospects

The total acres of alfalfa hay harvested in Kansas remained fairly stable between 1991 and 1995 at about 830 thousand acres, or 3.9 percent of the state's harvested crop acres. In 1995, 850 thousand acres of alfalfa hay were harvested. About 3.23 million tons of alfalfa were produced, with an average yield of 3.8 tons per acre. With this level of acreage and yield, alfalfa hay production in Kansas represented about 3.8 percent of the total U.S. production.

Approximately 54 percent of the state's 1991 to 1995 alfalfa acreage was in central Kansas, with 24.2 and 22.1 percent in the western and eastern regions, respectively. Barton, Dickinson, Edwards, Finney, Gray, Marion, Pawnee, Reno, and Sedgwick counties consistently rank at the top in total alfalfa-hay acreage. Alfalfa hay is produced under both nonirrigated and irrigated cropping practices, with most of the acreage in western Kansas being irrigated.

Each producer must answer two questions when selecting crops and the acreage of each crop to produce: (1) Will this choice be profitable? (2) Will this add more to the total net income of my farm operation than other choices? That is, is this the most profitable choice?

The fixed, or overhead, costs of land and machinery ownership for alfalfa, wheat, soybeans, corn, and grain sorghum will be basically equal for the production period considered. The variable costs associated with each are the costs that need to be considered when selecting a given crop. Variable costs include labor, seed, herbicide, insecticide, fertilizer, fuel, oil, repairs, crop insurance, drying, custom work, crop consulting, and miscellaneous.

Variable costs will depend on the management practices used, tillage operations, labor efficiency, and type and fertility of the land. Each producer should develop the variable costs of production for alfalfa and any other crop alternatives. Expected yield and selling price need to be determined for each crop alternative.

Budgeted variable costs by item are shown for nonirrigated alfalfa-hay production in eastern, central, and western Kansas and for irrigated alfalfa-hay production. A producer may have higher or lower costs than presented in these budgets.

The prices used in these tables are NOT price forecasts. They are used to indicate the method of computing expected returns above variable costs. These projections should be considered valid only under the costs, production levels, and prices specified. Individuals and groups using the information provided should substitute costs, production levels, and prices valid for the locality, management level to be adopted, marketing circumstances for the location, and time period involved.

The decision to plant alfalfa or another crop alternative can be made by comparing the expected returns above variable costs for each crop. Returns above variable costs will depend on yields and prices. Each producer should use yields that are reasonable for the land or classes of land operated.

The producer also should take into account other variables such as previous crop rotation, livestock operation, and the machinery and labor requirements of each crop. Labor requirements for alfalfa hay are significantly higher than for other crops, unless the harvest is custom-hired. The market and associated marketing costs for alfalfa hay also need to be considered if the hay is not fed to livestock in the farm operation.

The type and amount of equipment, crop rotations, and farm size all affect the cost of production. The tillage practices used and their timing also affect yields and production costs. Each producer should compute the expected returns above variable costs for the farm operation as a means of selecting the crops and acreage of each crop to produce. When computing expected returns above variable costs, consider a number of price alternatives.

Table 8. *Expected Returns above Variable Costs for Alfalfa*

	Eastern	Central	Western	Irrigated*	My farm
Yield per acre (tons)	3.3	3.5	2.2	6.5	________
Returns:					
Total returns	**$248.88**	**$267.83**	**$173.46**	**$485.21**	________
Variable costs:					
Labor	$47.70	48.60	31.50	29.25	________
Seed	5.70	5.70	4.50	8.55	________
Herbicide	0.00	0.00	0.00	17.95	________
Insecticide	11.55	11.55	11.55	11.55	________
Fertilizer and lime	13.05	15.00	10.50	22.40	________
Fuel and oil (crop)	17.15	17.65	13.60	9.45	________
Fuel and oil (pumping)	0.00	0.00	0.00	65.05	________
Machinery repairs	25.00	26.65	20.00	43.20	________
Irrigation repairs	0.00	0.00	0.00	7.20	________
Crop insurance	0.00	0.00	0.00	0.00	________
Drying	0.00	0.00	0.00	0.00	________
Custom hire	0.00	0.00	0.00	0.00	________
Crop consulting	0.00	0.00	0.00	6.50	________
Miscellaneous	5.25	5.25	5.00	7.00	________
Interest on variable costs (10 percent)	6.27	6.52	4.83	11.41	________
Total variable costs	**$131.67**	**$136.92**	**$101.48**	**$239.51**	________
Expected returns above variable costs	$117.21	$130.91	$ 71.98	$245.70	________

* The irrigated alfalfa budget is based on variable costs for center-pivot irrigation practices.

Table 9. *Estimated Variable Costs of Production per Acre*

	Eastern	Central	Western	Irrigated*	My farm
Alfalfa	$132	$137	$101	$240	________
Wheat	89	80	77	139	________
Soybeans	105	99	--	169	________
Corn	164	157	115	331	________
Grain sorghum	114	99	85	187	________

* The irrigated-crop budgets are based on variable costs for center-pivot irrigation practices.

Table 10. Estimated Costs and Returns for Alfalfa Compared with Other Crops for Kansas

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
Eastern Kansas								
Alfalfa (ton)	3.3	$72.50	$9.63	$249	$132	$117	$80	$37
Wheat (bu)	35	4.15	9.63	155	89	66	80	– 14
Soybeans (bu)	30	6.95	9.63	218	105	113	80	33
Corn (bu)	93	2.95	9.63	284	164	120	80	40
Grain sorghum (bu)	75	2.80	9.63	220	114	106	80	26

* Based on $700 per acre land at 6 percent; $3.50 per acre taxes. Depreciation, interest, and insurance on $255 per acre machinery investment equals $34.

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
Central Kansas								
Alfalfa (ton)	3.5	$72.50	$14.08	$268	$137	$131	$77	$54
Wheat (bu)	35	4.15	14.08	159	80	79	77	2
Soybeans (bu)	30	6.95	14.08	223	99	124	77	47
Corn (bu)	83	2.95	14.08	259	157	102	77	25
Grain sorghum (bu)	65	2.80	14.08	196	99	97	77	20

* Based on $675 per acre land at 6 percent; $3.83 per acre taxes. Depreciation, interest, and insurance on $245 per acre machinery investment equals $33.

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
Western Kansas								
Alfalfa (ton)	2.2	$72.50	$13.96	$173	$101	$72	$60	$12
Wheat (bu)	40	4.15	13.96	180	77	103	77	26
Corn (bu)	75	2.95	13.96	235	115	120	77	43
Grain sorghum (bu)	60	2.80	13.96	182	85	97	77	20

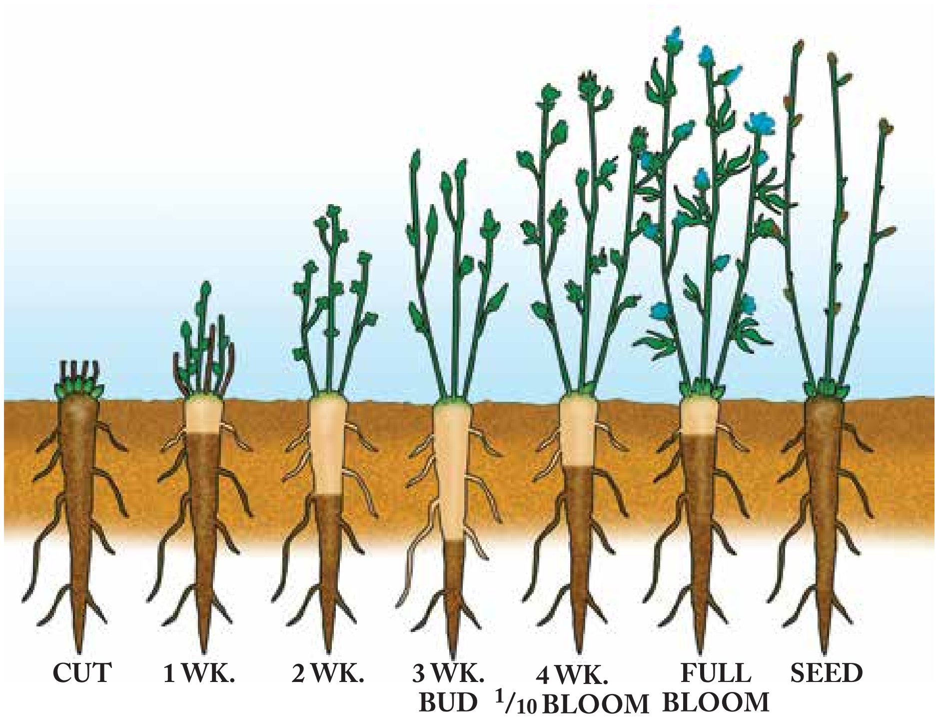
* Based on 1 acre of land for each acre of alfalfa harvested and 1.5 acres of land for each acre of all other crops harvested. $525 per acre at 6 percent; $3.94 per acre taxes. Depreciation, interest, and insurance on $190 per acre machinery investment equals $26.

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
Irrigated crops								
Alfalfa (ton)	6.5	$72.50	$13.96	$485	$240	$245	$172	$73
Wheat (bu)	65	4.15	13.96	284	139	145	172	– 27
Soybeans (bu)	50	6.95	13.96	361	169	192	172	20
Corn (bu)	190	2.95	13.96	574	331	243	172	71
Grain sorghum (bu)	110	2.80	13.96	322	187	135	172	– 37

* Represents center-pivot irrigation practices and was based on $865 per acre land at 6 percent; $4.33 per acre taxes. Depreciation, interest, and insurance on $930 per acre machinery and irrigation equipment investment of $930 equals $116.

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
My farm								
Alfalfa (ton)	_____	_____	______	_____	_____	_____	_____	_____
Wheat (bu)	_____	_____	______	_____	_____	_____	_____	_____
Soybeans (bu)	_____	_____	______	_____	_____	_____	_____	_____
Corn (bu)	_____	_____	______	_____	_____	_____	_____	_____
Grain sorghum (bu)	_____	_____	______	_____	_____	_____	_____	_____

Seasonal Carbohydrate Root Reserve



Stored carbohydrates in taproots are necessary for rapid regrowth, winter survival, and root-rot resistance. This illustration shows the changes occurring as a result of regrowth after cutting. The darker area of the taproot represents the approximate carbohydrate level.

Source: NCR-184, *Alfalfa Diseases in the Midwest*

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