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Hay Production in Texas

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Forage and forage-based livestock production enterprises are big business in the U.S. and in Texas. The latest United States Department of Agriculture (USDA) statistics (2008) indicate that hay harvested in the U.S. was worth approximately $18.8 billion, third in overall value among crops grown in the U.S. Only corn and soybeans exceeded the value of hay (Table 1). The value of all cows and calves marketed in 2008 was estimated at approximately $50 billion.

Twelve states account for approximately 63 percent of the total U.S. cow herd and of these top 12 states, Texas has nearly twice the cattle of the next closest state. These same 12 states represent 49 percent of the total hay acreage harvested and 48 percent of the total hay value (Table 2). In 2008, Texans harvested approximately 4.4 million acres of hay worth an estimated $1 billion. Whether you look at national data or at Texas data, hay production is a valuable enterprise that contributes significantly to our state and national economies.

Table 1. Value of commodities produced in the US during 2008.

Commodity	Value all US ($)	Value Texas ($)
Barley	1,208,173,000	–
Corn	47,377,576,000	1,218,000,000
Cotton	3,538,573,000	1,141,536,000
Cows and calves	49,843,322,000	7,630,837,000
Hay	18,777,138,000	1,014,813,000
Rice	3,390,666,000	194,635,000
Rye	50,447,000	–
Soybeans	27,398,638,000	45,510,000
Sugarbeets/ sugarcane	2,221,701,000	–
Tobacco	1,482,437,000	–
	16,568,211,000	737,550,000

(USDA National Agricultural Statistic Service)

Table 2. Beef cow and calf inventories for the top 12 states as of 2008. (USDA National Agricultural Statistic Service)

State	Number of head	Acres harvested	Hay value ($)
Texas	13,600,000	4,430,000	1,014,813,000
Kansas	6,650,000	2,750,000	711,043,000
Nebraska	6,450,000	2,570,000	544,292,000
California	5,450,000	1,520,000	1,705,934,000
Oklahoma	5,400,000	2,910,000	479,010,000
Missouri	4,250,000	1,020,000	844,130,000
Iowa	4,000,000	1,550,000	699,590,000
South Dakota	3,700,000	3,850,000	762,000,000
Wisconsin	3,350,000	1,900,000	521,360,000
Colorado	2,750,000	1,570,000	612,084,000
Montana	2,600,000	2,400,000	474,160,000
Kentucky	2,400,000	2,640,000	547,920,000
Total 12 States	60,600,000	29,110,000	8,916,336,000
US Total	96,034,500	60,062,000	18,777,138,000
% of US Total	**63**	**49**	**48**

(USDA National Agricultural Statistic Service)

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Selecting Forage Species

The forage species you choose will have a large impact on the nutritive value of your hay. The species must be adapted for the soil type, rainfall and other environmental conditions of the location where you intend to produce the hay. You will want a species with multiple year yields, high nutritive value, winter hardiness, persistence, and disease resistance. When choosing a forage species for hay, you must also consider the nutrient requirements of the animals that will likely be target of the hay feeding as well as the cost to establish, maintain and continue hay production. An annual forage species will have to be established each year, which can increase the cost of hay production. A perennial forage species will not need to be reestablished each year. Although cool-season annual grasses (small grains, ryegrass), and some legumes are harvested for hay each spring, most hay operations in Texas are based on warm-season perennial grasses. The following are some common forage types and species used for hay production.

Warm-Season Perennial Grasses

Bermudagrass (*Cynodon dactylon*) spreads mainly by rhizomes (underground stems) and stolons (horizontal aboveground stems). This grass tolerates a wide range of soil types and soil pH values, making it adapted to most of the southern U.S. Bermudagrass provides good nutrition for cows during the growing season and is used extensively to produce hay for winter feeding. There are numerous varieties of bermudagrass, both seeded (common, Cheyenne, Wrangler) and hybrid (Tifton 85, Coastal, Jiggs, etc.).

Bahiagrass (*Paspalum notatum*) is established from seed. The grass is very tolerant of low-fertility, acid soils, but does respond to nitrogen and potassium. It is best used for grazing rather than hay production. Once bahiagrass grows 10 to 12 inches tall, it produces little new growth and loses nutritive value the longer it stands. It is necessary, therefore, to harvest every 30 to 35 days to maintain forage nutritive value.

Dallisgrass (*Paspalum dilatatum*) is palatable and has a higher level of nutritive value than bahiagrass and some bermudagrass varieties, and it can retain its nutritive value later into the summer. Dallisgrass, however, produces a lower dry matter yield than some bermudagrass varieties and can be difficult to establish because the seed germinate slowly. Dallisgrass is also subject to ergot (*Claviceps* spp.) infection, which can be toxic to cattle if they eat infected seed heads. Dallisgrass can be used as a hay crop as long as it is cut before seed heads develop.

Johnsongrass (*Sorghum halepense*) is better suited for hay production than for grazing because it can accumulate prussic acid in its leaves and poison livestock. Young, tender, fast-growing plants are more likely to be toxic than mature plants. Johnsongrass should be harvested at heading. Once the hay has dried enough to be safely baled, prussic acid will have volatilized to nontoxic levels. Additionally, johnsongrass has a strong potential for nitrate accumulation when subjected to stress and/or high nitrogen fertilization. Unlike prussic acid, nitrate levels do not decline after cutting or baling. Proper sampling and testing are required to ensure the hay is safe to feed.

Old World bluestems *(Bothriochloa ischaemum, B. bladhii,* and *Dichanthium* spp.) include several species of grasses introduced from Europe and Asia from 1920 to 1965. These bunchgrasses are well adapted to North, Northcentral, and Central Texas because they are cold and drought tolerant. Though Old World bluestems respond to good fertility, the grasses are generally persistent with little or no fertilization. These grasses usually establish quickly and persist for long periods of time.

Warm-Season Annual Grasses

Crabgrass (*Digitaria sanguinalis* and *D. ischaemum*) has high nutritive value and is well adapted to sandy soils. Though often considered a weedy species, it is palatable and can be used for hay production. Dry matter yield, however, is usually less than well-managed bermudagrass. Crabgrass hay usually has higher nutritive value than bermudagrass, bahiagrass, or the more commonly used summer annual grasses such as pearl millet or sorghum-sudan hybrids. Crabgrass should be harvested in the boot to heading stages (normally 18 to 24 inches high); this can allow for at least two harvests a year. Once crabgrass reaches the mature seed stage, forage nutritive value begins to decline. Crabgrass hay normally cures more slowly than bermudagrass but more quickly than sorghum-sudan hybrids or pearl millet.

Pearl millet (*Pennisetum glaucum*) can be used for pasture, silage or hay, though making hay is usually somewhat more difficult because of the large stems. Millet may require a hay conditioner (a piece of equipment that crimps and crushes newly cut hay to promote faster and more even drying) and more drying days than the fine-stemmed species such as bermudagrass. Pearl millet is known to have a strong potential for nitrate accumulation when subjected to stress and/or high nitrogen fertilization. As noted previously, nitrate levels do not decline after cutting or baling. Proper sampling and testing are required to ensure the hay is safe to feed.

Sorghum-sudan hybrid (*Sorghum bicolor x drummondii*) is a warm-season annual that grows rapidly and produces high yields and high nutritive value hay. Like pearl millet, though, sorghum-sudan hybrids also have large stems, which require conditioning and extra drying time. Similar to johnsongrass, sorghum-sudangrass also has a strong potential for nitrate accumulation when subjected to stress and/or high nitrogen fertilization and can produce prussic acid under stress conditions such as drought or frost. Again, proper sampling and testing are required to ensure the hay is safe to feed.

Cool-Season Annual Grasses

Ryegrass (*Lolium multiflorum*) is used primarily for pasture, though it can be used for hay or silage. It tolerates a variety of soil types and grows better in wet soils than any other cool-season annual grass. Ryegrass is sensitive to acid soil pH values below 5.5. It is a popular choice for late winter/early spring grazing and hay production.

Oat (*Avena sativa*), though primarily used for grain and pasture, can also be used as a hay crop. Oat is generally more cold sensitive than other small grain species and can suffer winterkill. Harvesting oat hay in the boot stage produces the highest overall forage nutritive value, but delaying harvest until the soft dough stage will produce a greater yield.

Wheat (*Triticum aestivum*) is primarily used for grain and pasture though it can also be used for hay. It should be harvested at the boot to early heading stage.

Rye (*Secale cereale*) is generally the most winter hardy of the cool-season annual grasses. Rye is also the most productive cool-season annual grass on low-fertility, well-drained sandy soils. Rye matures earlier in the spring than most wheat varieties but generally produces more forage in the fall than wheat.

Triticale (*Triticum secale*) is a cross between wheat and rye. Grain from triticale is used as a feed by the livestock industry. It can be planted earlier, often produces more forage, and has a longer grazing period than many varieties of wheat or rye. Triticale tolerates drought and pests better than wheat.

Cool-Season Perennial Grasses

Tall fescue (*Festuca arundinacea*) can be used for pasture, hay and/or erosion control. Tall fescue grows on a wide variety of soil types, but it performs best on loam or clay soils that have some water-holding capacity. Tall fescue also tolerates flooded conditions and grows well in soils that are typically too wet for many other forage grasses. For highest nutritive value, the first harvest should be cut in the late boot stage. Subsequent harvests can be made as growth permits. Tall fescue's rainfall and temperature requirements generally limit its production to northeast Texas.

Cool-Season Legumes

Alfalfa (*Medicago sativa*) is a perennial with high yield potential and nutritive value. Alfalfa hay is very digestible and can be high in crude protein, energy, vitamins, and minerals. Alfalfa harvested pre-bloom typically has higher nutritive value and is more palatable than more mature hay. Alfalfa contaminated with blister beetle may cause blister beetle poisoning, which can cause colic, urinary infections, dehydration, shock, and death, especially in horses.

Red clover (*Trifolium pratense*) is a short-lived perennial that can last 2 to 3 years. It is better suited for hay production than other clovers because it grows upright and late into the season. Red clover should be reserved for well drained soils, as this legume does poorly when planted on wet soils.

Arrowleaf clover (*Trifolium vesiculosum*) can be used for grazing or for hay. It can be grazed until mid-April and harvested at the early bloom stage in mid-May.

Because regrowth is usually poor, you should expect only one harvest. A mower/conditioner will help this hay dry more quickly. Mixtures of arrowleaf clover and annual ryegrass can make an excellent quality hay crop.

Warm-Season Legumes

Soybean *(Glycine max)* can be used for grazing or for hay. You can harvest soybeans at any stage of growth, however, dry matter yield and nutritive value are balanced when harvest occurs when there is a full pod at one of the upper nodes. Unlike most other legume crops used for hay, soybean foliage and pods both provide digestible protein.

The species of forage used for hay production will have a large impact on hay nutritive value. Generally, legumes have higher nutritive value than grasses, and cool-season grasses have higher nutritive value than warm-season grasses at the same stage of maturity (Table 3). Within each type, nutritive value varies widely with maturity.

Animal Nutrient Needs

The principle limiting nutrients for ruminants (cattle, goats, sheep, etc.) are either energy (total digestible nutrients, TDN) or protein (crude protein, CP). For cattle grazing dormant pastures or consuming poor quality hay, protein is usually the most limiting nutrient. When you have to buy supplemental feed, protein is often the most expensive component. Forage nutritive value has dramatic effects on livestock productivity (weight gain, reproduction, etc.), so it is critical to match the nutritive value of the hay to the nutrient requirements of the target animal.

Table 3. Approximate hay yield, crude protein content, and total digestible nutrient (TDN) content of various hay crops under good soil fertility and management.

Type of hay crop	Annual (A) or perennial (P)	Usual hay yield (tons/A)	Approximate usual nutrient level: Crude protein (%)	Approximate usual nutrient level: TDN (%)
Cool-season				
Alfalfa (early bloom)	P	3-6	17-22	57-62
Arrowleaf clover	A	2-3	14-17	56-61
Oats	A	1-4	8-10	55-60
Orchardgrass	P	2-5	12-15	55-60
Red clover	P	2-4	14-16	57-62
Rye	A	1-4	8-10	50-55
Ryegrass	A	1-4	10-16	56-62
Soybean	A	2-3	15-18	54-58
Tall fescue	P	2-4	10-15	55-60
Warm-season				
Annual lespedeza	A	1-2	14-17	52-58
Bahiagrass	P	3-5	9-11	50-56
Coastal bermudagrass (4 weeks)	P	5-8	10-14	52-58
Common bermudagrass	P	2-6	9-11	50-56
Dallisgrass	P	2-4	9-12	50-56
Johnsongrass	P	2-5	10-14	50-56
Pearl millet	A	2-6	8-12	50-58
Sericea lespedeza	P	1-3	14-17	50-55
Sudangrass	A	2-6	9-12	55-60

Source: D.M. Ball, C.S. Hoveland, and G.D. Lacefield. *Southern Forages*, 4th edition.

Beef cattle

For beef cattle operations, the most common source of stored feed is hay. If hay is harvested at the proper stage of plant growth and stored properly, it can, with the possible exception of grazing, provide nutrients at the lowest possible cost. A cow's nutrient requirement is the greatest 60 to 80 days after calving. Stockering young, growing cattle requires an average daily gain of at least 1.5 pounds for the season, and high-quality forage is essential to meeting this goal. A growing beef steer or heifer requires forage with about 12 percent CP and 65 to 68 percent TDN.

Horses

The "best" hay for any given horse depends on its particular nutrient requirements. Barren mares, retirees, and horses used for light recreational riding have relatively low nutrient requirements; growing horses, lactating mares, and performance horses have higher nutrient requirements. Mid-to late-maturity hay is usually more desirable for horses with lower nutrient requirements, while early-maturity hays are more appropriate for horses with high nutrient needs. Early-maturity hays are more palatable and work effectively for horses with poor appetites. With good management, most hay species or mixtures can be satisfactory for horses. Horse-quality hay begins at 10% CP and should approach 12% or more.

Sheep and goats

Small ruminants have somewhat higher metabolic rates and require more nutrition than large animals. Hay for sheep and goats should contain more protein and be more digestible than hay produced for the dry, pregnant cow. Like other livestock, the nutrient needs of these animals will vary, so match the hay you feed to their nutrient requirements.

Soil Fertility

Soil fertility is critical to forage production and nutritive value. Therefore, a sound soil fertility program is critical for providing adequate nutrients for the growing plant. In a forage system this involves more than just adding nitrogen (N), phosphorus (P) and potassium (K). It also involves monitoring soil compaction, soil pH, nutrient applications and removal rates, and in some cases, subsoil nutrient status.

Soil testing is the most important tool in forage production. But before collecting soil samples for testing you should take a land inventory and evaluate your forage needs.

Land inventory

The productivity of soil across a field can vary significantly due to changes in slope, soil depth, soil moisture retention, and surface and subsoil textures. It is difficult to improve land that is sloped and has poor soil texture and low moisture retention. The USDA's Natural Resources Conservation Service (NRCS) provides County Soil Surveys that document these different soil properties based on soil profile samples, aerial topography maps, on-site assessment of vegetation and streams, and other visual data. Most Texas counties have recent soil surveys that were completed after 1960. These surveys can be found at many public libraries, at local NRCS offices, or online using the Soil Web Survey (*http://websoilsurvey.nrcs.usda.gov*).

In addition to the soil survey, producers can evaluate their land by observing how plants and forages respond to rainfall and prolonged periods of drought. How well or poorly forages grow depends on the soil's water-holding capacity, root development potential, and nutrient availability. Soil survey data, coupled with observations regarding forage production, can provide valuable information about soil differences across a given landscape. Water-holding capacity, influenced by soil texture and slope, is often the main determinant of good land for hay production.

As you develop your soil and forage management plan, you will need to consider each field's size and shape in relation to the fertilizer spreaders and harvest equipment you plan to use. You must also consider the field proximity to other crops or properties that might restrict or prevent the use of certain pesticides, limestone, or other nutrients.

Forage needs

If you are growing hay only for sale, fertilize and plant every acre on which you can grow hay profitably. If you are growing hay for a livestock operation, you will need hay for the number of animal units (1000 pound cow with nursing calf) multiplied by 26 pounds of hay per day, multiplied by the number of feeding days and adjusted for some level of feeding waste. For example, if you have 100 head of cattle and plan 120 days of feeding and considering 20% waste, you will need to bale and have on hand, 390,000 pounds of hay.

26 pounds × 100 head × 120 days ÷ .8
(20 percent waste)
= 390,000 pounds of hay

This quantity of hay could be produced on 98 acres of land (single 2-ton hay cutting), 49 acres of land (two 2-ton hay cuttings) or 33 acres of land (three 2-ton hay cuttings). Forage for hay production requires considerably more nutrients and management than is required for grazing. Hay production, therefore, should be reserved for the highest yielding sites. Estimate the tonnage of hay you will need and grow this hay on the fewest number of acres possible.

Soil sampling

Once you have determined how much hay you need, you can use the land inventory to decide where to collect soil samples and how to manage fields for grazing or hay production. Mapping and collecting soil samples properly will help you develop an accurate and efficient nutrient management plan. While one sample per 40 acres should suffice for land intended for grazing, you should collect one sample per 10 acres in hay fields (Fig. 1).

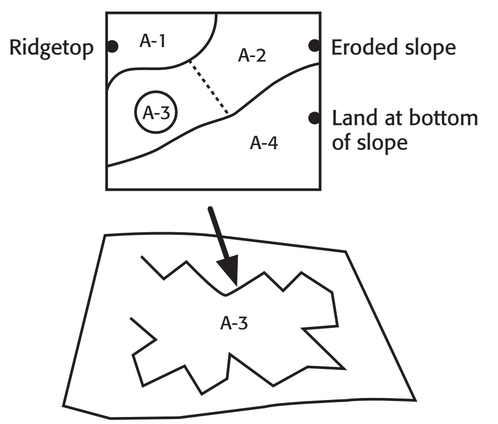

Figure 1. Soil sampling for pastures.

The composite soil sample for each area you want to analyze should consist of 10 to 15 subsamples. These subsamples should be broken up thoroughly and mixed in a clean plastic bucket. Then place 1 pint of this mixture in a soil sample bag. This is the composite sample. Soil sample bags are typically available from your local county extension agent.

Sampling procedure

- Take one composite sample for every 10 to 40 acres. Take separate samples for areas with different soil types, different land uses or fertilizer uses, or different terrain.
- Routine analysis requires approximately 1 pint of the composite soil.
- Avoid sampling small gullies, slight field depressions, terrace waterways, or atypical areas.
- When sampling fertilized fields, avoid sampling directly in a fertilized band.
- After applying manure or litter to a field, wait 90 days before taking soil samples unless the manure or litter has been thoroughly incorporated.

Composite samples

- Take 10 to 15 subsamples from different locations in the area to be managed.
- Use a soil auger or soil sampling tube and sample 6 inches deep. You can use an auger bit powered by an electric drill to collect samples that are 0 to 6 inches deep. Regardless of method, take all samples from the same depth.
- Clear plant litter from the surface, but do not remove decomposed black (humus) material.
- When using a spade/sharpshooter, dig a V-shaped hole and take a 1-inch slice from the smooth side of the hole; then take a 1- x 1-inch core from the middle of that slice.
- Create composite samples by placing soil subsamples in a clean plastic bucket or other non-metallic container and thoroughly mixing them. One pint of this mixture is a composite sample that represents the field or area you want analyzed.
- Air-drying the samples before sending them to the laboratory will improve the nitrate-nitrogen analysis. Do not use heat to dry samples.
- Fill the soil sample bag completely. Do not submit samples in old vegetable cans, tobacco cans, match boxes, or glass containers. If you submit more than one sample bag, label them 1 of 2, 2 of 2, etc.

Under some circumstances, you may need to take deeper soil samples to better understand the nutrient status of the deeper soil profile. For example, soils with very sandy surfaces often have very low potassium-holding capacity and annual soil testing will suggest the need for potassium fertilization. If the soil has a shallow clay layer within 12 inches of the surface, however, it may not need additional potassium fertilizer because potassium is available in the clay layer. The Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory is evaluating profile soil testing for forage systems but does not currently make any formal recommendations for forage profile soil samples.

The recommendations that you receive from the testing laboratory will assume that:

1) compaction and non-chemical soil properties will not limit yield;
2) you will control weeds;
3) your yield goal is reasonable for the field to be fertilized;
4) the soil sample was representative of the area analyzed;
5) the crop species you select are suitable for the climate and soil; and
6) you will address all nutrient, pH, and salinity limitations.

Evaluating Soil Characteristics

The first factor to evaluate is the soil pH. Most forage species require soil pH levels of at least 5.8. Soils with low pH levels can have higher concentrations of soluble aluminum and manganese. This condition limits root development and restricts uptake of water and most plant nutrients, including nutrients from fertilizer applications. You can increase the soil pH by applying ground or finely crushed limestone. Unless the limestone is worked into the soil completely and there is adequate soil moisture, however, you may not see changes in the soil pH immediately. Recent applications of nitrogen may also decrease the soil pH by creating new acidity. In many Texas landscapes, free limestone (calcium carbonate) makes the soil pH moderately high and limits the availability of phosphorus and most micronutrients. Unless high sodium levels cause the high pH, there is no effective mechanism for lowering soil pH. If this is the case, you must select forages that can tolerate the high soil pH.

Soluble salts

High levels of soluble salts in the soil can limit water uptake and forage productivity. In most cases, soils become saline because of poor irrigation water quality, the encroachment of tidal water, or the lack of leaching. The only effective way to reduce soil salinity is by leaching the salts down through the soil profile with abundant rainfall or irrigation. Though choices are limited, you could decide to plant more salt-tolerant forages

Nitrogen

Most perennial Texas forages scavenge nitrogen very well and leave little carryover at the end of the growing season. Though nitrogen recommendations are based on species and yield goals, it generally takes approximately 50 pounds of nitrogen to produce 1 ton of high-protein, warm-season perennial grass hay. This level of nitrogen is required for all subsequent hay harvests. For grazing systems, nitrogen recommendations are based on species and assume equal grazing intensity and urine and fecal deposits across a given field. Research shows that as much as 50 percent of the nitrogen applied as fertilizer and taken up by the forage is recycled through animal defecation into new forage growth within 4 weeks of grazing. This efficiency is lost when livestock are allowed to congregate near ponds and shade areas. Rotational stocking with water in each paddock will help ensure efficient nitrogen management and capture.

Phosphorus

After nitrogen, phosphorus is often the second most limiting nutrient. Phosphorous plays a major role in transferring energy from one part of the plant to another, enabling cell division and plant growth. Many areas of Texas have inherently low amounts of soil phosphorus. Phosphorous is less available in deeper soil and can be depleted when it is not replaced after hay harvests. Soil tests can determine phosphorus levels in forage fields; however, a common symptom of low phosphorous is the decline of desired forage species (e.g., bermudagrass) and the invasion of grasses that require less phosphorus (e.g., bahiagrass). Rotational stocking systems effectively maintain phosphorus availability. In these systems, fecal deposits are quickly mineralized so the phosphorus can be used immediately. In haying systems, an average of 14 pounds P_2O_5 is removed for each ton of dry matter harvested. Phosphorus can quickly limit plant growth if it is not replaced.

Potassium

Potassium's primary role in plants is associated with water transport. Without adequate potassium plants take up less water and nutrients and forage yield decreases. Historically, low potassium was only a problem in the sandier areas of Texas, but hay production in more clayey soils has also depleted potassium from the surface and subsurface of these soils. About 45 pounds of K_2O are removed per ton of dry matter harvested. The removal rate in grazing systems is near zero, but as mentioned above, rotational stocking will help ensure more even redistribution of potassium.

Other nutrients

While other plant nutrients can be limiting, the frequency and pattern of these limitations is very difficult to generalize. Producers should evaluate the status of these other nutrients with annual soil tests.

Weed Management

Weed infestation generally increases after drought or when land is not managed properly. When fertilized according to laboratory recommendations, forage crops such as bermudagrass produce significantly more dry matter and can usually out-compete weed species. Without fertilization, however, weed species generally have the competitive advantage.

Weeds hurt forage production by intercepting sunlight and removing moisture and nutrients forage crops need for growth. Weed flowers in the hay meadow are usually the first indication of a weed problem. Unfortunately, by the time weeds flower, it is usually too late to apply a herbicide or it takes additional herbicide to achieve control. A better strategy is to scout pastures early every growing season to determine whether weed infestation is at a level requiring intervention.

Prevention

The best way to mange weeds is to prevent them from becoming a problem. Proper seeding rates and forage selection, combined with good fertility, produce forage stands that are better able to compete with weed species. This approach to weed management is usually more cost-effective than applying herbicide later. Even with the best planting and soil management, however, most hay operations will require some form of weed control.

Chemical

When used appropriately, chemical weed management is safe and cost-effective. The first step is to correctly identify the weed species, then select the most effective herbicide.

The second step is to follow the label directions precisely to ensure that you use the herbicide safely, effectively and economically. Labels list safety precautions, proper application rates and times, target species, and cleanup and disposal information. Even if you have used certain herbicides for many years, check the label each year to see if the product instructions have changed. The Texas Agrilife Extension Service publishes weed control guides to help you select herbicides.

Prescribed fire

Prescribed fire is generally used to suppress woody species and is often used after herbicide treatments. Prescribed fire can extend the life of the herbicide application and repeated fires, especially warm-season fires, can convert wooded areas into savannas that provide better livestock and/or wildlife habitat. Many producers also find the savanna ecosystem more aesthetically pleasing. Although prescribed fire is not common in east Texas, its value as a management tool should not be overlooked.

Mechanical

Mechanical weed management methods can be effective in regions that have problems with mesquite, huisache, blackbrush, and other woody species. Mechanical methods are generally less effective and more costly than chemical controls (Table 4). Mechanical treatments, primarily mowing or shredding, can actually make managing species like persimmon more difficult. Though Table 4 may appear to indicate only a slight economical advantage to the herbicide treatment, each season usually requires more than one mechanical treatment. When you consider even two trips across the field with a mower, the economic advantage of herbicides is immediately apparent.

Table 4. Economic comparison: Mechanical and chemical weed control.

Item	40-hp tractor with 6-foot rotary mower	40-hp tractor with 30-foot boom sprayer
Labor cost/hour	$10.00	$10.00
Acres/hour	2.73	14.18
Costs		
Fixed cost/acre	$5.58	$1.53
Operating cost/acre	$5.00	$1.11
Labor cost/acre	$3.66	$0.71
Herbicide cost/acre	-0-	$8.25
Total cost/acre	**$14.24**	**$11.50**

Source: Clary and Redmon, 2008.

Harvesting Hay

When to harvest

As forage plants mature, each bite provides less nutrition because the crude protein content decreases with maturity. Fiber components in the forage also become less degradable. As well, mature plants contain more lignin, which is either an indigestible or only slowly digestible compound that provides no energy to the animal. The bottom line is that forage nutritive value declines as the plant matures.

The optimum nutritive value of a forage plant depends on the target animal. Capturing that nutritive value requires careful attention to the maturity of the various forage species. Bermudagrass, for example, should be harvested at approximately 15 inches tall if the target animal is a dry, pregnant cow. This height is a good compromise between dry matter yield and nutritive value in the plant at that stage. Mature horses, on the other hand, typically have higher nutrient requirements. For horses, bermudagrass should be harvested 7 to 10 days earlier, or at approximately 12 inches in height, to capture a higher level of nutrients. Cool-season grasses should generally be harvested in the early boot stage.

Many hay crops are harvested when the dry matter yield will be highest. Since the nutritive value of these crops is generally lower, animals will usually need supplements during the winter or during droughts when fed overly mature forages. It is usually less expensive to fertilize appropriately and harvest at the correct stage of maturity than it is to purchase supplement. The goal, then, is to harvest hay when yield and nutritive value are balanced for the target animal species and class.

Harvest steps

The first step in hay production is the actual cutting of the hay. Hay mowers fall mainly into two classes — sickle-bar cutters (Fig. 2) and disk mowers (Fig. 3). Sickle-bar mowers have long cutting heads with reciprocating teeth. Disk mowers have cutting heads with several small rotating cutters. In the past, it was difficult to adjust cutting height and most mowers left a stubble height of 2 inches or less. Cutters today are more adjustable and a higher cut leaves some leaf material to support photosynthesis and encourages a more rapid recovery from the harvest.

Figure 2. Sickle-bar type cutter. Photo by permission of Roger Kechter

Figure 3. Disk mower cutter. Photo courtesy of New Holland North America.

After cutting, the hay should remain in the field to dry or "field cure." The dried or cured forage is then raked (Figs. 4 and 5) into windrows that are the width of the take-up header of the baler. Sometimes a heavy dew, high relative humidity, or rain will cause the windrow to be dry on top but wet underneath. When this happens you can use an implement called a tedder to turn the windrow over to help it dry (Fig. 6). Once the moisture content in the windrow has reached the appropriate level, the forage can be baled into round or square bales.

Figure 4. Dried forage being raked into windrows. Photo by permission of Dave Smith.

Figure 5. Dried forage after being raked into a windrow. Photo by permission of Larry Redmon.

Figure 6. Tedder used for inverting dried forage to speed drying. Photo by permission of Pat Meyer.

Moisture content

Most forages contain about 70 to 80 percent moisture when they are cut. Field curing (drying) the forage as quickly as possible will help preserve its nutritive value, especially the energy portion. How quickly forage dries depends on humidity, temperature, wind speed, and solar radiation. Hay cures quickly on hot, sunny, windy days with low relative humidity; it cures more slowly when conditions are cool, cloudy or humid.

As long as the forage moisture content is above 40 percent, hay will continue to respire (burn up carbohydrates), leaving less energy for the livestock that ultimately consumes the hay. Harvested forage that is left to be rained on may exceed 40 percent moisture content for an extended period of time and lose substantial energy content due to leaching of non-structural carbohydrates. Rain can also shatter leaves off harvested forage and reduce both the crude protein and energy levels of the hay. It is better to wait for good curing conditions than to take a chance that rain will fall on mowed hay. Figure 7 shows the effect of rained-on hay on animal performance.

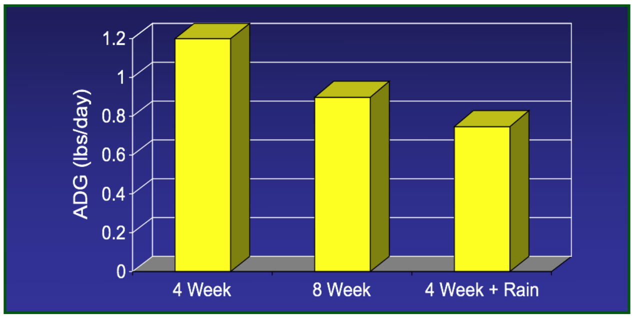

Figure 7. Effect of rain and maturity of hay on animal performance. (Source: McCullough & Burton, 1962)

At baling, the moisture content of hay for large round bales should not exceed 18 percent; for small square bales, moisture content should not exceed 20 percent. Although experienced producers can estimate the moisture content by touch, a moisture meter will provide a more accurate reading. One way to get consistent readings with a moisture meter is to use an 18-inch length of 2-inch diameter PVC pipe with a threaded cap on one end. Pack the harvested forage into the PVC pipe, then insert the moisture meter into the hay to obtain a reading. It is important to pack the tube to the same density each time. When finished, simply unscrew the cap and push the hay out with a wooden dowel. You can then replace the cap and sample other parts of the field.

The temperature of hay baled will increase during the first few weeks after baling. This increase is called “sweating” or “going through a sweat.” It is mainly caused by microbial activity, though it can include some final plant respiration. As the hay dries it loses roughly 1 percent of dry matter for each percent of moisture.

At a moisture content of greater than 20 percent up to 35 percent, mold production becomes a great concern because it consumes nutrients in the hay and reduces its nutritive value. Mold also creates heat from respiration and produces toxins that make the hay less palatable. While mold-related heat up to about 120 degrees F does not damage hay nutritive value, higher temperatures can. Protein breakdown begins at temperatures above 120 degrees F and browning begins at about 140 degrees F. This browning reaction (carmelization) can further increase temperature and take forage nearly to the point of combustion. These high temperatures also bind up much of the protein in the forage, making it unavailable to the animal.

(Hay temperatures less than 120 degrees F are considered safe; between 120 degrees F and 140 degrees F, monitor closely; between 140 degrees and 180 degrees F hay is likely to spontaneously combust.)

Hay moisture and temperature are not constant and should be monitored periodically. Hay normally reaches its peak temperature from 7 to14 days after baling, but temperature may rise for as long as 30 days. If you observe high bale temperatures or are unsure about what is happening to the bales, store suspect bales outside and away from other dry haystacks. Safety and nutritional considerations make it critical that you bale hay at the appropriate moisture content.

Baling high-moisture hay

Under certain circumstances you may need to harvest hay at higher than recommended moisture content. There are three ways to handle high-moisture hay.

Inhibitors make it possible to safely store hay that is baled at up to 30 percent moisture. Inhibitors also help reduce leaf loss during baling and can reduce potential rain damage. The most commonly used inhibitors are propionic acid (propionates) and ammonia (applied at about 1 percent of wet forage weight). Propionates disrupt the metabolic processes of plant and microbial respiration. Ammonia can improve both the crude protein and digestibility levels of the hay by preventing mold growth and keeping the hay at safe temperature levels. Both products, however, can pose significant health risks to those applying the materials. According to Extension specialists at Ohio State University (Weiss and Underwood, 1992),

- Propionic acid is corrosive and can damage machines and injure workers.
- Anhydrous ammonia is difficult to apply and is a hazardous chemical.
- Propionic acid and anhydrous ammonia are the only preservatives that are consistently effective on hay containing 25 to 30 percent moisture.
- Other preservatives may be effective on hay containing 20 to 25 percent moisture, but many have not been scientifically tested.
- Preservatives other than ammonia and urea do not improve feeding value, but can reduce storage losses.
- It is essential to know the moisture content of the hay. Hay containing more than 30 percent moisture should not be baled even with a preservative.

Drying agents are typically water-based solutions of potassium carbonate (K_2CO_3) and/or sodium carbonate (Na_2CO_3) with an appropriate surfactant to help them spread over the harvested forage. The solution is applied immediately after mowing and speeds up the drying process by disrupting the waxy cuticle of the stem and allowing moisture to escape from the harvested forage. These products are generally safe to use, though high relative humidity can reduce their effectiveness and unexpected rainfall can wash them off altogether. It is important to note that drying agents, unlike inhibitors, do NOT allow for baling hay at a higher moisture level. Drying agents do not affect forage nutritive value.

Haylage involves baling forage with 45 to 55 percent moisture content, then putting the bales into airtight storage. Haylage is typically wrapped in plastic to exclude air. Aerobic (free oxygen requiring) bacteria then consume the oxygen remaining inside the hay within a few hours. Under these conditions, anaerobic (non-free oxygen requiring) bacteria reduce the forage pH and preserve the forage in a more or less "pickled" state. The low pH inhibits mold and respiration losses that typically occur in high-moisture bales. Haylage does not, however, attain as low a pH as silage so it cannot be stored as long. The cost to wrap long strings of round bales (Fig. 8) or individual bales (Fig. 9) is about $5 to $7 per bale. While haylage reduces leaf shatter loss and allows you to preserve high-moisture forage, it is typically fed on-farm because it cannot be moved easily.

Figure 8. Multiple high moisture "haylage" bales being wrapped in plastic. Photo by permission of Larry Redmon.

Figure 9. High moisture "haylage" bales individually wrapped in plastic. Photo by permission of Pat Meyer.

Forage Analysis

A forage analysis can determine the nutritive value and/or any potential toxicity of forage. With this information you can calculate whether or not you will need supplemental protein, energy or minerals. You must sample the hay correctly to get an accurate analysis, and each lot of hay should be sampled independently. For the purposes of hay sampling, a ***lot*** of hay refers to "all forage harvested and baled from one field at one harvest date and stored under similar conditions."

You should obtain one composite sample for each lot of hay by taking sub-samples from at least 10 percent of each lot's bales. This composite sample will represent the nutritive value for that lot of hay. Currently, a forage analysis for crude protein at the Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory for many forage species costs $5.00 per sample.

Sampling bales

The ends and outer edges of bales are often weathered and decayed, so taking samples from these areas can understate the true nutritive value of the hay. The ideal way to sample hay is to use a bale probe, which removes a 1-inch-diameter core. Consult your county Extension agent to find out how to purchase or borrow a bale probe.

On round bales, cores should be taken toward the center, midway up the side of the bale. Sampling near ends or bottoms of bales will not give you a representative sample. Remove the outer ½ inch of the bale surface so the sample will not be contaminated with dust or debris. Then drill or core 12 to 18 inches into the bale and carefully put the sample into a paper sack. Repeat this procedure on several other bales from the same field and harvest date. Mix the subsamples thoroughly and submit the composite sample to the laboratory along with the laboratory submittal form. You should collect one composite sample for every 25 to 30 bales from a given field and cutting. For very large lots of hay you should sample at least 10 percent of the baled hay.

On square bales, take sample cores from the ends of bales toward the center. Remove the outer ½ inch of hay, then drill 12 to 18 inches into the bale. Carefully place the sample into a paper sack, and then sample six to eight other bales from the same field and cutting. Mix the samples thoroughly, label the composite sample, and submit it to the laboratory with the submittal form. Collect one composite sample for every 400 bales from a given field and cutting.

Sampling pastures

It is more difficult to obtain an accurate forage sample from the field than from a bale. You have to know the height at which the forage will be harvested and differences in fertilization from one area of the pasture to another. Mixing samples from areas that have received different rates of manure or fertilizer will skew the final laboratory analysis. Each area should be sampled separately according to its particular management and fertilization practices or type of grass. To obtain a subsample, cut, clip or tear the forage at the intended haying height. Be careful not to pull the entire plant out of the ground. Gather subsamples from 10 to 15 areas within a given pasture or field (not to exceed 40 acres). Combine all the subsamples and place them in an appropriate paper sack or envelope. Do not use plastic bags, fertilizer bags, or feed sacks to submit samples. Label the container with the field and sample identification and submit it with the laboratory submittal form.

Analysis for Nutritive Value

Nutrient needs for grazing animals vary according to kind (cattle, sheep, goats, horses) and class (mature, dry pregnant, lactating, growing). Although minerals and vitamins are important to the overall health and performance of these animals, **energy** and **crude protein** are the most important components of forage nutrition.

Energy

Forage can be broadly divided into ***cell contents*** (protein, sugar, starch) and ***cell walls or fiber*** (cellulose, hemicelluloses, lignin). Non-ruminants (horses and pigs) get energy directly from forage while ruminants (cattle, sheep, goats, and white-tailed deer) get energy indirectly through degradation of the forage's carbohydrates and fiber in the rumen. By-products of the fermentation process include volatile fatty acids (VFAs) that are absorbed into the ruminant's bloodstream and metabolized for energy.

Peter Van Soest (Cornell University) developed the system for analyzing fiber constituents using detergents. Most laboratories use this method to identify two important aspects of fiber; neutral detergent fiber and acid detergent fiber.

Neutral Detergent Fiber (NDF) represents the components (hemicelluloses, cellulose, lignin) of plant cell walls, which are degradable depending on the plant's maturity and degree of lignification. NDF is the residue left after boiling a forage sample in a neutral detergent. Neutral detergent fiber also contains lignin, which is either not digestible or very slowly digestible. Neutral detergent fiber is correlated with dry matter intake in that as NDF increases, intake generally decreases.

Acid Detergent Fiber (ADF) is determined by processing the residue from NDF analysis or an intact forage sample in a sulfuric acid solution. This process releases ADF solubles containing hemicelluloses and fiber-bound protein into solution. The fiber that remains is referred to as ADF and is mostly cellulose and lignin. The cellulose in ADF is more or less digestible depending on the maturity of the forage. The lignin is mostly indigestible. Although the hemicelluloses go into solution during the acid detergent procedure, the hemicelluloses are not necessarily more digestible than cellulose, because hemicelluloses are more closely related with lignin. Acid detergent fiber content is an indirect indicator of overall forage digestibility or energy; as ADF increases total digestibility generally decreases. ADF is also used to estimate the total digestible nutrient (TDN) value of forage.

Crude Protein

Crude protein (CP) is the second important component of forage nutritive value. True **proteins** are complex structures made up of amino acids. Laboratory analyses for protein, however, are expressed as ***crude*** protein because the analysis is not for protein but for total nitrogen. A crude estimate of total protein is obtained by multiplying the percentage of total nitrogen by a constant of 6.25. Some of the nitrogen in the CP estimate may actually include non-protein nitrogenous compounds. How well the partially available protein fraction can be used by animals depends primarily on the crop species and maturity.

Since hay may be the only source of nutrients for livestock during the winter, it is critical to know their nutrient requirements to ensure that the hay you feed will meet that need. Crude protein and TDN requirements for various kinds and classes of livestock are shown in Table 5.

Other than measuring animal performance, the only way to determine whether your hay is adequate is by laboratory analysis. If you overestimate the nutritive value of the hay, cattle will calve in poor condition and take longer to breed again. In the case of horses, low quality hay is the primary cause of impaction colic. If you underestimate the hay's nutritive value you may end up buying expensive supplements that are unnecessary. Timely forage analysis can prevent either of these costly scenarios.

Table 5. Crude protein (CP) and total digestible nutrients (TDN) levels required in diets of different kinds and classes of grazing livestock.

Animal kind/class	% CP	% TDN
Growing beef steer		
450 lbs (1.5 lb/day gain)	11–13	65
650 lbs (1.7 lb/day gain)	10–11	68
Beef cow		
Lactating	10-12	60
Dry, pregnant	7-8	50
Sheep		
Lamb (finishing)	12	70
Ewe (lactating)	13	65
Ewe (maintenance)	9	55
Fallow deer		
Doe (lactating)	14–6	66
Growing buck	12–14	60-64
Meat-type goat		
Doe (lactating)	12	62
Growing buck	12–13	62-66
Horse (maintenance)	10–11	70

Source: Ball et al. 2002

Forage Toxicity

Nitrate accumulation

Ammonium nitrogen produces the best plant growth, but nitrate nitrogen is the form primarily taken up by plants. Soil microorganisms quickly convert ammonium nitrogen to nitrate nitrogen, so even when ammonium and urea-based fertilizers are used, most of the nitrogen taken up by plants is in the nitrate form. Under good growing conditions, plants reduce nitrates to ammonium, which in turn is converted into amino acids and other proteins. When forage growth is slowed or stopped by drought, extended periods of cool and/or cloudy weather, soil nutrient imbalances, etc., nitrates can accumulate in the forage to a toxic level. Nitrates are nonvolatile and if you harvest and bale high-nitrate hay, that nitrate level will remain constant in the bales.

The warm-season annual grasses (forage sorghums, sorghum-sudan hybrids, pearl millet) and johnsongrass are of greatest interest to hay producers as these plants are the most susceptible to nitrate accumulation.

The Texas Veterinary Medical Diagnostic Laboratory (TVMDL) at Texas A&M University has suggested it is safe to feed forage containing 1 percent nitrate (10,000 ppm on a dry-matter basis) to healthy ruminants. Forage with a higher nitrate percentage may be fed if it is ground and mixed with nitrate-free forage to an overall level of less than 1 percent on a dry-matter basis. Forage containing 0.5 to 1 percent nitrate should not be fed to weakened cattle unless your veterinarian has approved it. Note that the 1 percent nitrate level set by the TVMDL is significantly higher than levels suggested by other southern universities and assumes cattle are healthy, well conditioned, and being fed a high-energy diet.

Nitrate poisoning

In healthy cattle, the nitrate consumed in normal forages is converted into nitrite and then to ammonia, amino acids, and finally proteins. If forage contains too much nitrate, the animals cannot convert it all into protein quickly enough and nitrite levels build up. Nitrite is then adsorbed directly into the bloodstream through the rumen wall where it reacts with hemoglobin to form methhemoglobin. Hemoglobin carries oxygen in the blood, but methhemoglobin does not and can cause an animal to die from asphyxiation. You can determine whether an animal has died from nitrate poisoning by cutting a recently deceased animal; the blood will be dark and then turn red as it reacts with oxygen in the air.

Though monogastrics (horses, mules, swine, etc.) are less sensitive to nitrate toxicity than ruminants, there have been reported cases of horses becoming ill from high-nitrate hay. An animal's condition affects its ability to tolerate nitrates, so consult your veterinarian before feeding forage that contains nitrates.

Sampling for nitrates

Nitrate accumulation is highest in the lower stem of the plant and lowest in the leaves. To sample forage before harvesting, create a composite sample from at least 10 to 15 areas with the same fertility and moisture conditions. Do not mix plants from "good" and "bad" parts of the field. Create different composite samples for those particular areas. Send the samples to the laboratory in clean paper sacks. Do not use plastic bags because the high moisture content will make the samples mold, which interferes with the nitrate analysis.

To sample bales for nitrate, take core samples with a bale probe. If you don't have a probe available, split the bale open and collect lower stems of individual plants to ensure the highest possible nitrate level is revealed by the analysis. High-nitrate bales are particularly hazardous to timid animals because more aggressive cattle tend to eat the leaves and more palatable upper stems first and leave only the lower stems, which have higher concentrations of nitrate.

Field testing

To test for nitrates in the field you can use qualitative spot color methods and/or quantitative methods that use colorimeters and nitrate electrodes. One quick test is the diphenylamine spot test. The Texas AgriLife Extension Service Soil, Water, and Forage Testing Laboratory provides these quick-test kits for nitrate analysis, but the kits contain sulfuric acid and the lab is not allowed to ship them. They must be hand delivered or picked up.

For this test, a single drop of the acid reagent is placed on a freshly split plant stem. This method works only on moist plants with stems thick enough to split and receive the test reagent. If the reagent turns dark blue within 5 seconds, the forage contains nitrate. If the color does not change immediately, there is no nitrate; however, the reagent will eventually turn the stem dark brown or black by caramelizing the plant sugars and carbohydrates. Follow up any positive field test with laboratory analysis. Dried plants, hay, silage, fine-stemmed grasses, and similar material should be tested in a laboratory. It is important to remember that field-testing should be used only as a qualitative tool and is not precise enough to use as a basis for mixing feeds.

Interpreting nitrate reports

Nitrate content may be expressed as actual nitrate (% NO_3) or as nitrate-N (% NO_3-N) values. The Texas AgriLife Extension Service Soil, Water, and Forage Testing Laboratory reports nitrate in forage as actual nitrate, which differs from plant nitrate analysis for other plants. Plant nitrates are expressed as ppm nitrate-N. To convert ppm nitrate-N to percent, divide by 10,000. To convert nitrate-N levels to actual nitrate, multiply by 4.42. Be sure you understand your laboratory's reporting method to ensure you don't feed toxic levels of nitrate to livestock.

$$\text{Nitrate-N ppm} \div 10{,}000 = \text{percent nitrate-N}$$
$$\text{Percent nitrate-N} \times 4.42 = \text{percent nitrate}$$

Managing nitrate hay

There are few options for managing baled hay containing nitrates other than grinding and mixing it with good forage to dilute the nitrate level to less than 1 percent. It is best to mix similar forage types so that the feed has a uniform particle size and palatability. The stems dictate the optimum size, but generally, the smaller the better. A handful of mixed, ground feed should contain portions of all plant parts of the forages used in the mix. The uniform size and palatability will help limit selective feeding by livestock. You should not grind or mix forages that contain more than 2.5 percent nitrate. Hay with this level of nitrate should not be used for livestock feed or bedding.

Prussic acid

Prussic acid in forages can pose a significant risk to grazing livestock, but in well-cured hay, prussic acid is rarely an issue. Though prussic acid accumulation occurs under the same conditions that cause nitrate accumulation, prussic acid volatilizes to a safe level during the curing process. For additional information on managing prussic acid in forages, refer to Extension publication **E-543**, "Nitrates and Prussic Acid in Forages."

Buying and Selling Hay

While large quantities of hay are sold as small square bales, cow-calf producers primarily use large round bales because they require less labor to store and feed. Most hay for cow-calf production systems is sold on a ***per-round bale basis*** and there are two major problems with this.

First, buying hay on a ***per-round bale*** basis does not tell you the nutritive value of the bale. Hay is often advertised as "well" or "heavily fertilized," but these terms are not precise. The actual levels of crude protein and digestible energy, and other nutritive characteristics of the forage should be established through laboratory analysis so producers can make sound purchasing and feeding decisions. Why should a bale with only 6 percent crude protein sell for the same price as a bale that contains 14 percent crude protein? In most cases they should not, yet these differences are not obvious to the naked eye. "Well fertilized" hay may not meet the animal's nutrient requirements, and supplementation can dramatically increase the cost of the feeding program. Hay with higher nutritive value, as documented by a laboratory, may cost more, but it could prove to be a more economical strategy if it eliminates the need for supplements.

The other problem with buying by the bale is that the amount of dry matter being sold or purchased is unknown. Bale size varies tremendously with the baling equipment used, the skill of the equipment operator, the forage species, the moisture content of the bale, the type of wrap used, and the way the hay was stored. Economic analysis shows bermudagrass hay costs $110 to $120 per ton to produce when all inputs, (labor, equipment, fuel, repairs, taxes, depreciation, fertility, herbicide, etc.) are accounted for. Given this cost, a 1,200-pound round bale priced at $45 is a good buy, but if the bale weighs only 700 pounds, it is not. When hay is sold by the bale, rather than by weight, either the seller or the purchaser is getting short-changed.

The answer to selling or buying round bales of unknown weight and nutritive value is to analyze and weigh the hay. The nutritive value and weight of each lot of hay can be established by a lab test and a trip across a set of scales. The actual dry weight of hay is determined by adjusting for moisture content as measured by a moisture probe.

Storing Hay

When you fertilize according to soil test recommendations, harvest the forage at the appropriate stage of maturity, and carefully cure and bale your hay, it ends up being an expensive commodity worth protecting from the elements. Hay that is stored outside can lose significant dry matter and nutritive value in a relatively short time (Table 6). Even a 4-inch band on the outer surface of a 6-foot diameter round bale can represent a 21 percent lossof dry matter and nutritive value (Table 7). Typically, hay bales stored outside for several months develop at least 5 or 6 inches of outer surface that has no feed value and that animals will refuse. Economic analyses indicate that by preventing hay loss, a hay barn can pay for itself in 4 to 6 years. Of course, this payback period varies according to barn construction and geographic location.

Round hay bales can be stored outside, but losses will be significant compared to storage under a roof. To

Table 6. Effect of storage system on dry matter loss of ryegrass hay stored for 7 months.

Storage system	Dry matter (%)	Animal refusal (%)	Total loss (%)
Ground	28	22	50
Gravel	31	17	48
Tires	35	6	41
Rack	26	6	32
Rack with cover	12	2	14
Barn	2	1	3

Source: Nelson et al. 1983

Table 7. Effect of depth of weathering loss on total hay loss.

Bale diameter (feet)	Depth of weathered band (inches)	Amount of forage loss (%)
5	4	25
5	6	36
5	12	64
5	18	84
5	24	96
6	4	21
6	6	31
6	12	56
6	18	75
6	24	89

reduce losses, hay can be stored under tarps specifically designed for this task. When round hay bales are stored in the field, they should be stored in rows with the flat ends of the bales together to minimize exposure to the elements. The rows should be stored on a well-drained slope, running north and south to maximize east – west sun exposure and help dry them after rains.

Summary

Hay production for feeding livestock is a well-established agricultural practice. As you plan for your forage needs, it is important to produce enough hay to meet your livestock's nutrient requirements during periods of drought, ice, or snow. Forages for harvest should be fertilized appropriately and should be harvested at the desired stage of maturity. Baled hay should then be field cured to the proper level of moisture content and stored under cover to prevent loss of dry matter and nutritive value. Hay should be analyzed to establish the nutritive value in the bales and to determine whether supplemental nutrition will be required during the feeding period. Finally, certain forage species that may accumulate toxic levels of nitrates should be carefully analyzed to ensure the hay is will not sicken or kill livestock.

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