EDUCATION •RESEARCH • EXTENSION
The Texas A&M University System

Soil & Crop Sciences

Managing for High Quality Hay

Mr Charles Stichler
Assocaite Professor and Extension Agronomist
Texas A&M Research and Extension Center at Uvalde

Dr. David Bade
Professor and Extension Forage Specialist
Texas A&M Research and Extension Center at Bryan

College of Agriculture and Life Sciences
The Texas Agricultural Experiment Station
The Texas Agricultural Extension Service

Texas A&M University System
Department of Soil and Crop Sciences
College Station, Texas 77843-2474

SCS-1997-02

Managing for High Quality Hay

Charles Stichler
Associate Professor and Extension Agronomist
Texas Agricultural Extension Service
Texas A&M Research and Extension Center at Uvalde

Dr. David Bade
Professor and Extension Forage Specialist
Texas Agricultural Extension Service
Texas A&M Research and Extension Center at Bryan, Texas

Hay is the most common source of stored feed used in livestock operations. Surveys show that 86% of the harvested hay is used on the producer's own farm; therefore, producers should be concerned with producing quality hay. Hay harvested at the proper stage of plant growth and undamaged by weather provides nutrients at a minimal cost compared to other high quality supplemental feeds. Forage varies greatly in quality and it should be remembered that high quality or low quality forage can be produced from most forage species. Legumes such as alfalfa and clovers, generally contain a higher percentage of protein, minerals and vitamins than grasses. However, grasses usually produce higher forage yields and higher amounts of total digestible nutrients per acre than legumes. Insects, disease and harvest problems are fewer on grasses than legumes and grasses require fewer production inputs. Regardless of the forage, quality hay production requires special attention to details and constant management.

The range of quality varies greatly based on climate, fertility, weed control, stage of maturity at harvest, harvest conditions and storage. Forages of almost every kind are preserved as hay for livestock feed, yet much of it is poor quality and fails to provide the nutrition needed. Low quality hay requires extra supplementation to meet animal requirements.

High quality hay is palatable dry forage, highly digestible, with sufficient nutrients to meet the nutritional needs of the class of livestock to which it is being fed. High quality hay requires a minimum of or no additional supplementation, is bailed at a moisture level to prevent spoilage yet moist enough to prevent shattering losses, and is free of foreign matter, weeds and molds. Determination of high quality hay is a combination of both physical factors and the nutritional status.

Factors That Determine Hay Quality

Factors that determine hay quality include stage of maturity at harvest, soil fertility, nutritional status of the plant, available moisture during the growing season, season of the year, ratio of leaves to stems and stem size, weed control, foreign matter, and harvesting, weather at harvest and storage. Of all the factors that influence quality, stage of maturity or age of the plant at harvest is the most important. About 70% of the quality of hay is determined by stage of maturity at harvest. As a plant matures toward heading, flowering and seed formation, the growth pattern changes from leaf production to hard stem formation. The digestible portion of the plant tissue decreases rapidly with each stage. Maturity effects the ratio of digestible leaves to indigestible stems which determines both the nutritive content and digestibility of forages. A 1% increase in digestibility of a warm season forage results in a 5% increase in animal performance.

Immature plants cells have a thin primary cell wall and are succulent with soft flexible tissue that is high in water and water soluble nutrients. Immature leafy forage plants contain easily digestible nutrients while old, mature stems and leaves contain complex nutrients and mature indigestible fiber. As plants begin to form seed, cells mature and a secondary wall composed of cellulose and lignin begins to develop to add rigidity to the plant. Lignin is indigestible and is comparable to wood. For example, Coastal bermudagrass, which is 12 inches tall can be 58% digestible in the top third of the plant, 54% digestible in the middle third, and only 50% digestible in the bottom third. Coastal bermudagrass harvested at 6 weeks of age has only 50% of the crude protein content and 80% of the energy of hay harvested at 4 weeks of age.

Since leaves are more digestible than stems and contain most of the nutrients, the higher the leaf content, the higher the quality. Additionally, seed heads are usually produced on the end of stems which are devoid of leaves, decreasing the leaf to stem ratios. To determine the maturity, look for seed heads. As a guide, grass hays with only a few immature seed heads is high quality, however, as the number and amount of mature seed in the heads increase, the quality decreases.

The proper stage of growth for harvesting forages is the time when the greatest amount of total digestible nutrients per acre may be obtained. This usually represents the best compromise between quality and yield. Generally, the younger the crop at the time of harvest, the higher the quality but the lower the yield. The more mature the crop at time of harvest, the higher the yield but the lower the quality. Crude protein content drops in all crops and crude fiber increases with maturity as shown in Table 1 and 2.

Research also indicates that forages are higher in quality during spring and fall and lower in quality during mid-summer. Hence hay harvested during the spring will tend to be higher in forage quality than hay harvested in July and August.

Table 1.

Forage	Stage of Growth	% Crude Protetin	% Crude Fiber
Alfalfa	Early bloom Full bloom	19.3 16.9	27.3 31.7
Coastal Bermudagrass	3 week growth 7-8 weeks growth	18.3 6.7	24.2 25.5
Oats	Pre-boot Early bloom	27.6 15.3	19.8 28.0
Sudangrass	Early boot Early bloom	16.8 8.1	30.9 36.4
Johnsongrass	Early boot Half bloom Mature seed	15.0 8.6 5.6	31.2 36.0 37.9

Table 2

Clipping Frequency (weeks)	Yield/Acre (tons)	Percent Crude Protein	Percent Leaf	Percent Stem	Percent Fiber	Invetro Dry Matter Digestibility
3	7.9	18.5	83	17	27.0	65.2
4	8.4	16.4	79	21	29.1	61.9
5	9.2	15.4	70	30	30.6	59.3
6	10.3	13.3	62	38	31.6	58.0
8	10.2	10.7	56	44	32.9	54.1
12	10.4	9.0	51	49	33.4	51.0

Fertility and Water Interaction

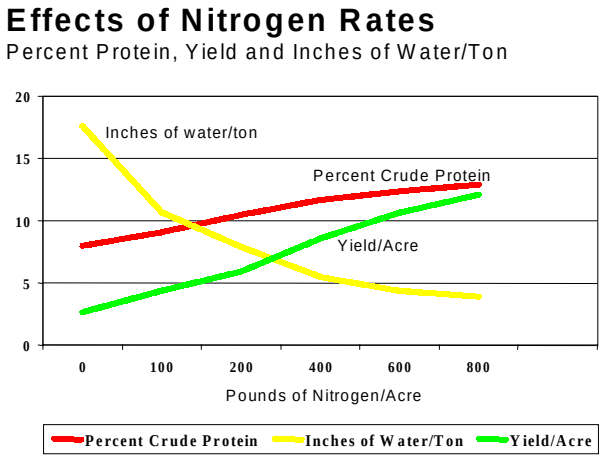
Nitrogen content of a forage is a direct measure of its protein content. The nitrogen that is extracted from a forage is multiplied by a factor of 6.25 and reported as percent crude protein. Thus, a forage containing 2 percent nitrogen contains 12.50 percent crude protein. Nitrogen fertility rates for grasses then greatly influences the crude protein levels in forages harvested at the right stage of maturity. Table 3 indicates the pounds of nitrogen contained in dried forages at different production levels.

Table 3. Pounds of Nitrogen Contained in Forages

% Nitrogen	% Crude Protein	1 Ton/ Acre	2 Tons/ Acre	3 Tons/ Acre	4 Tons/ Acre	6 Tons/ Acre
1.0	6.3	20	40	60	80	120
1.3	8.1	26	52	78	104	156
1.6	10	32	64	96	128	192
2.0	12.5	40	80	120	160	240
3.0	18.8	60	120	180	240	360
4.0	25.0	80	160	240	320	480

Since most nutrients are absorbed by roots when dissolved in water, the uptake of nitrogen and other nutrients is dependent on the moisture status in the soil. When nitrogen is absorbed with adequate water, new plant proteins and cell formation create growth. Without adequate nitrogen levels, grasses continue to pick up water which evaporates through the leaves, but new growth is not produced.

For the best combination of yield and quality without contributing to excess N in runoff or groundwater, N rates should be adjusted to the yield potential. The following chart developed from research near Crystal City, Texas shows the relationship between nitrogen, quality and water use efficiency.



Phosphorus, potassium and other nutrients are also critical to maintaining stands and producing quality hay. A soil test should be taken once a year to determine the amount of plant nutrients remaining after the previous years productions to replace those elements removed by harvest.

The nutrients in one ton of forage is approximately 50 pounds of nitrogen, 15 pounds of phosphorus and 40 pounds of potassium. (See bulletin No. B-6035 Crop Nutrient Needs for South and Southwest Texas for additional fertility information.) If three tons of forage are removed annually in the form of hay, it will equal approximately a total of 150-45-120 pounds of nutrients removed.

High yielding production removes other nutrients as well. Soils in hay fields should be periodically sampled to determine the levels of pH (Table 4), sulfur, calcium, zinc, iron, etc. If the nutrient levels in the soil are dropping, they should be replaced as needed. Generally, nutrients other than nitrogen can be applied once per year.

Table 4. Effect of soil pH on relative efficiency of nutrient uptake

Soil pH	Nitrogen	Phosphorus	Potassium
4.5	21	8	21
5.0	38	10	30
5.5	52	15	45
6.0	63	15	60
7.0	70	30	60

Harvesting

The goal of harvesting should be to maintain the highest nutritive quality as possible through cutting at the proper stage of maturity, promoting rapid drydown, maintaining high leaf content and timely baling at the right moisture content. Since living cells continue to respire and use energy, hay should be managed to dry the forage to below 40% as rapidly as possible. Most plants are almost 80% water and continue to metabolize cellular carbohydrates and sugars until the moisture levels in the forage reach 40%. Tight windrows, moist soil and cloudy, high humidity conditions all delay drying and promote valuable energy losses.

Recent experiments (USDA) indicate that cattle prefer afternoon cut hay over morning cut hay. Since cells make sugars and carbohydrates in the presence of sunlight, afternoon cut hay may contain a higher percentage of highly digestible sugars and carbohydrates. Plants cut in the morning have partially depleted the supply while respiring or using energy through the night.

Harvesting practices that increase hay quality include cutting in the afternoon, laying hay down on dry ground or stubble to prevent soil moisture from rising into the windrow, raking operations that do not cause leaf loss and baling at the right moisture.

Bacteria and fungi that cause hay to deteriorate, need moisture to grow. If hay is baled at a too high moisture, bale heating occurs shortly after harvest. Microbes are not able to reproduce if moisture levels are below about 14%. Small bales are often referred to as needing to go through a "sweat" in the field prior to stacking. The "sweat" is an additional loss of moisture if the hay was baled too "green". Small 60-70 pound bales can be baled at 16-18% moisture. Hay stored in large round bales need to be dryer (14-16%) at baling since moisture is unable to escape from the center of a large bale.

Quality Losses

Growing high quality forages is only a part of producing high quality hay. Poor harvesting can result in as much as a 50% loss on digestible nutrients. Cutting forages past the optimum stage of maturity, rain leaching soluble nutrients (highly digestible nutrients) out of the cutting forages and prior to baling, respiration of plant tissues and leaf shattering from overly dry forages.

The biggest losses to quality are caused by delaying harvest from the optimum developmental stage. Alfalfa's digestibility declines 0.5% per day following flowering while Coastal bermudagrass digestibility declines 0.2% per day from 4-8 weeks of age.

The most highly digestible nutrients in plants are water soluble cell contents. The younger (immature, succulent) the plants, the more water soluble nutrients they contain, the older (more mature) the plants, the less water soluble nutrients they contain. Rain on cut forages causes nutrients to leach out of the plant cells and increase dry matter losses. The greater the amount of both the time the forage is wet and amount of rain after cutting washing through the hay, the greater the nutrient losses. In a Purdue University study, 1-inch of rain reduced the TDN content of field-cured hay 5% while dry matter losses from wind dried hay were 3.5% per inch of rain. In general, leaching losses are less for a fast short duration 1-inch rain than a slow soaking rain of the same amount. Losses are higher from dry forage than fresh cut forage.

Plant cells are living tissue that will continue to respire (burn energy) even after cutting. Cutting a plant off does not stop the tissue from continuing to live for a period of time. Drying causes the cells to die. When moisture drops below 40%, cell activity stops. Poor drying conditions allow continued respiration of readily digestible carbohydrates (energy) which can result in a 10-15% loss of the original dry matter. Coastal bermudagrass (Overton Experiment Station) changed from 11.1% crude protein and 51.6% TDN at cutting to 8.9% crude protein and 42% TDN at baling after two days of drying.

As hay dries, the leaves become brittle and may break apart or fall off the plant. Alfalfa's leaves are attached very delicately to the stems and are particularly prone to leaf loss when raked too often or when too dry. Raking losses can amount to 5-15% and poor baling practices can result in an additional 1-15% loss.

Storage Losses

The amount of storage losses are directly related to the moisture to which the hay is subjected. Hay that is baled at too high moisture will develop mold and bacterial degradation or even in extreme cases, catch fire. Moldy hay can cause digestion problems in livestock. As the hay is "digested" by microbes, dry matter losses occur. Hay should be kept ***dry***. Round bales stacked outside on wet soil will lose as much as 25% of its original weight in one year.

Summary

Close attention to all aspects of hay production will result in production of high quality and quantities of livestock feed.

ABC's of Forage Testing

NDF **Neutral Detergent Fiber** is a test that uses water to dissolve highly soluble components such as sugars and carbohydrates and proteins from the forage. NDF is a measure of the structural fiber in the plant. It is an excellent predictor of consumption.

ADF **Acid Detergent Fiber** is a measure of cellulose, lignin, silica, insoluble crude protein, and ash, which are the least digestible parts of the plant.

CF **Crude Fiber** is a measure of total plant fiber.

CP **Crude Protein** is an estimate of the amino acids/proteins in a hay/feed based on the total N in the material.

DP **Digestible Protein** is an estimate of the animal available crude protein.

DM **Dry Matter** is an oven dried weight or 0% moisture.

DDM **Digestible Dry Matter** is the percentage of digestible dry matter

TDN **Total Digestible Nutrients** is an estimate of the percent of total digestible nutrients. It is based on ADF of the quantity of available nutrients in the forage.