NEW HOLLAND

Haymaker's Handbook

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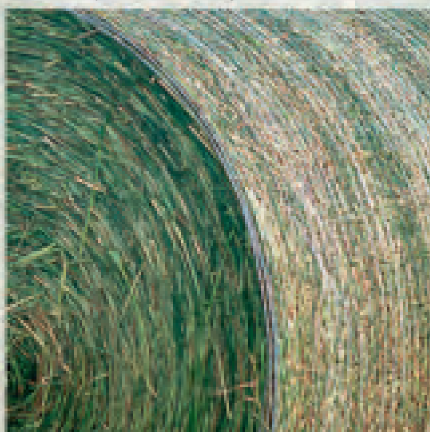

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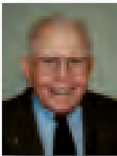

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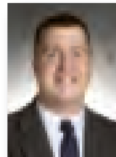
is Professor Emeritus of Agronomy at the Pennsylvania State University. He retired in 1983 after 26 years as Extension Forage Specialist. He emphasized forge production and quality and conducted many innovative programs including a statewide Alfalfa Growers Program, in-depth forage workshops for producers and agri-industry personnel, and many educational and competitive hay and hay crop silage shows. He has been a member of the American Society of Agronomy (ASA) and Crop Science Society of America (CSSA) for over 50 years and is a Fellow of both organizations. He is also a long time member of the American Forage & Grassland Council (AFGC) having served on its board and as president. He also served as Secretary-Treasurer of AFGC from 1970 until 1987 and was editor of the council's official voice - "Forage and Grassland Progress" from 1972 until it was discontinued in 1984. Internationally he was Chairman of the Governing Board for the XIV International Grassland Congress held at the University of Kentucky in June 1981, and served on the International Grassland Congress Continuing Committee. He was co-founder of the Forage and Grassland Foundation and served as its president. He was also co-founder of the Pennsylvania Forage and Grassland Council in 1960 and served as its first president. He has received a number of awards including AFGC's Medallion and Presidential Citation and its Distinguished Grasslander Award, along with the ASA Agronomic Extension Education Award and the Pennsylvania Agricultural Advisory Council Distinguished Service Award.

Baylor authored several books including the 50 year histories of AFGC (1994), PFGC (2010), and the Atlantic Seedsmen's Association (2002). He was also contributing editor to New Holland's Haymaker's Handbooks published in 1975 and 1987.



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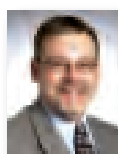

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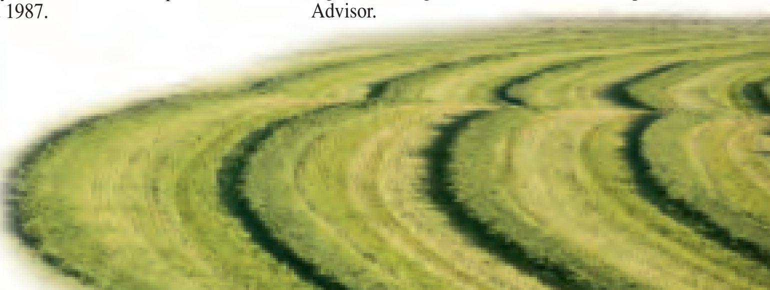


Table of Contents

Preface

Throughout its 115 year history, New Holland has always pursued a goal of finding innovative ways to simplify farmers' labors, making their lives less fatiguing, more pleasurable and more productive. From its freeze-proof engines of the early days to the world's first automatic pickup baler of the early '40's to the first Haybine® mower-conditioner in the '60's to the first Twin Rotor® combine and beyond, New Holland has reached its goal many times over.

With the addition of balers and forage harvesters to the New Holland product line began a focus on hay and forage production. Since then, New Holland has cultivated a passionate interest in the crops, their regional production methods, and the machines designed to handle them. Through a complete knowledge of these crops, methods and producers, the company has excelled in creating, manufacturing and servicing the machines needed for their harvest.

Early on, New Holland adopted several slogans to tie the company closely to hay and forage production in a way that went far beyond designing and building machines.

Slogans like "First in Grassland Farming," "Eat More Meat, Drink More Milk for a Healthy Agriculture," and "Hay in a Day" became synonymous with the name New Holland and established the firm as a leader in the field.

At the same time, the company became deeply involved with college and university agricultural departments and was very active in The American Forage and Grassland Council. Convinced that the pursuit of quality hay and forage production as it related to equipment was an important part of its mission, New Holland published a booklet in 1975 entitled *Haymaker's Handbook*, a small, abbreviated "how-to" guide book drawing together relevant university research, farmer know-how and company expertise to help both novices and well established farms understand the latest techniques and to improve upon hay and forage production. This booklet was so popular that it was revised and re-printed in 1987. Since then, it has successfully guided hundreds of forward-thinking producers around the world.

Although time has passed, many of the original messages contained within the early editions of *Haymaker's Handbook* remain valid despite the many landmark industry developments that have occurred. Today's renaissance in quality and focus on improved varieties and yields have driven this third edition of the popular handbook. Modern hay and forage crops are distinguished as valuable farm commodities and indispensable livestock feedstuffs. In reading this latest edition, a new generation of producers may discover the knowledge of prior generations and heed today's advanced production methods, learning to balance farm tradition with modern practices.

Hay Is Big Business

Hay is defined as grass or other plants, such as clover or alfalfa, cut and dried for fodder. On an annual basis, alfalfa is the single largest hay crop grown in the United States, representing 48% of the total tonnage harvested. The remaining 52% of the nation's hay crop comes from cereal crops such as oats, barley, wheat, and rye; cool season grasses including timothy, orchard grass, and fescues; warm season grasses such as Bermuda grass, Johnsongrass, switch-grass, and bluestems; and prairie grasses.

Hay production is a major agricultural business. In 2009, U.S. haymakers harvested 147 million tons of hay from 59.7 million acres of ground with an estimated market value of almost $15 billion! This places hay third in economic value, behind only corn and soybeans.

And, remember, big chunks of these acres are in semiarid areas where average yields are inherently low.

Hay is big business! It's made in every state in the United States and every province in Canada. In 2009, U.S. haymakers harvested 147 million tons of hay from 59.7 million acres of ground with an estimated market value of almost $15 billion.

FIGURE 1-1

Top 15 forage states

State Ranking Production	State	Total forage Production *(in thousand tons)*	Total Alfaifa Rank	Total Alfaifa Production *(in thousand tons)*	Total Other Hay Rank	Total Other Hay Production *(in thousand tons)*	Total Corn Silage Rank	Total Corn Silage Production *(in thousand tons)*	Total Green-chop Rank	Total Greenchop Production *(in thousand tons)*
1	Wisconsin	26,730	5	3,875	34	555	1	13,600	1	8,700
2	California	23,472	1	6,958	16	1,674	2	10,010	2	4,830
3	New York	15,554	26	805	17	1,667	3	8,460	3	4,622
4	Pennsylvania	14,986	18	1,450	10	2,205	4	8,190	4	3,141
5	Minnesota	14,672	4	3,900	22	1,350	5	7,600	5	1,822
6	Idaho	12,244	3	4,788	30	740	6	5,913	9	803
7	South Dakota	12,207	2	5,750	11	2,080	8	4,000	14	377
8	Texas	11,902	28	600	1	7,650	13	2,940	11	712
9	Kansas	11,080	6	3,655	6	3,570	10	3,420	13	435
10	Nebraska	10,289	7	3,610	8	2,625	9	3,780	17	274
11	Iowa	9,297	10	3,312	31	690	7	4,840	12	455
12	Missouri	8,975	25	840	2	7,200	28	800	18	135
13	Michigan	7,493	15	1,960	35	522	11	3,410	6	1,601
14	Kentucky	7,460	27	770	3	5,520	22	1,170	19	0
15	Ohio	7,325	21	1,292	19	1,584	12	3,400	8	1,049
	U.S. TOTAL	**287,163**		**71,030**		**76,412**		**108,209**		**31,512**

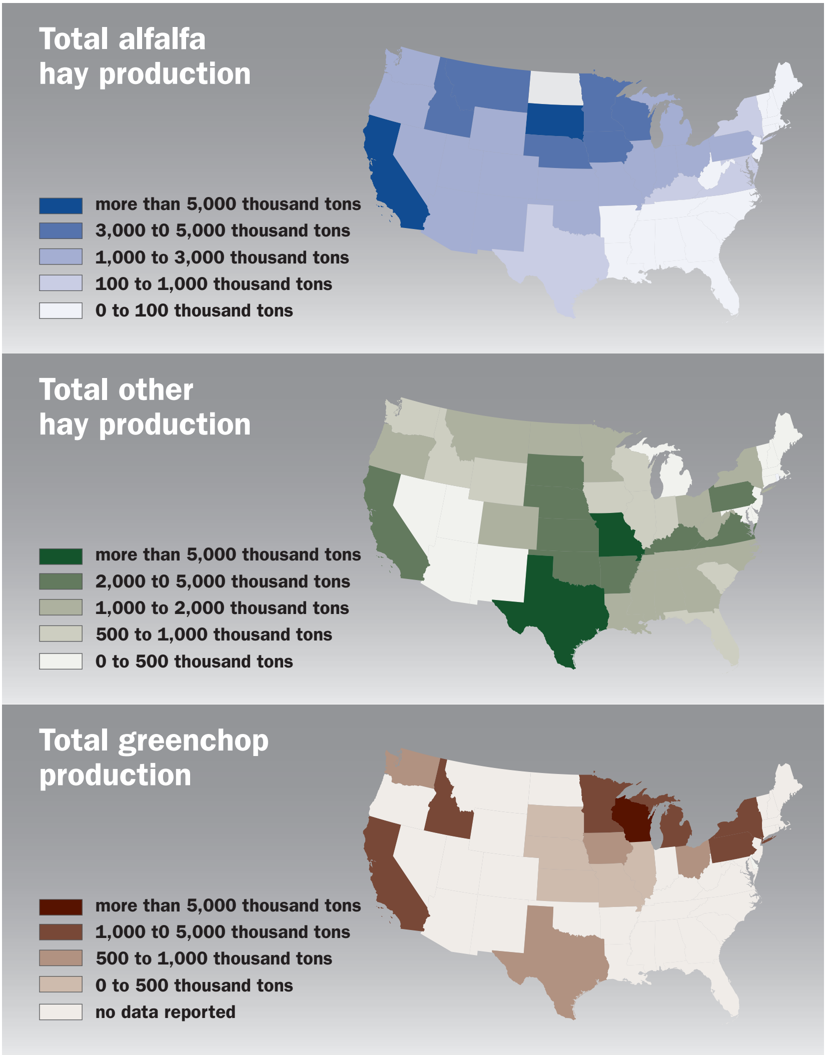
Source: Crop Production 2009 Summary Report, USDA, NASS; Statistical ties are represented by the same numerical ranking.

Source of charts/graphs: Courtesy of Progressive Forage Grower magazine.

Grown in Every State

While hay is third in estimated value among U.S. field crops, it is more widely grown and harvested than all other major field crops. Production of corn, wheat, cotton, soybeans, and other field crops are typical to specific regions or belts, but hay is grown in all 50 states and every province of Canada. The major reason for the wide geographic production of hay is that hay encompasses many species of plants, which can grow in both temperate and semiarid regions.

FIGURE 1-2



Within the U.S. in 2009, the top five forage producing states by total tonnage were Wisconsin, California, New York, Pennsylvania, and Minnesota. The top 15 states by tonnage for 2009 are shown in Figure 1-1. These states are also traditionally heavy dairy production states, and the dairy farm use of hay, corn silage and green chop drives the forage production in these states. The top five alfalfa producing states were California, South Dakota, Idaho, Minnesota, and Wisconsin. The alfalfa, corn silage and green chop production tend to be clustered in the far west, north central and northeast regions. The other hay category, which encompasses grass hays, is traditionally a south central and southeastern U.S. commodity.

Hay Utilization in the U.S.

Hay is an important source of energy and other nutrients in most livestock diets for several reasons, including cost, nutrient density, and availability. Figure 1-3 shows the average cost and nutrient density for several common livestock feedstuffs in the U.S. As can be seen, the hays (both alfalfa and grass) are among the most cost effective feeds for each of the nutrients listed.

Yields and Acreage Constant

The acreage and yields of all hay in the U.S. have remained fairly constant over the past 30 years (Figure 1-4). The low average yield for hays is typically due to lack of proper fertilization. However, when intensive management is applied to hay production, yields respond similarly to other major field crops. While the average yields for all hay is approximately 2.4 tons per acre, intensively managed yields on non-irrigated land can be 8 tons or greater, and irrigated land yields can easily be 10 tons or greater. An 8-ton alfalfa yield has roughly the same nutrient content as 200 bushels of corn, which is a well above average corn crop in the U.S.

Hay – A Vast Potential

The achievement of high yielding hay stands requires top level management all the way around. This starts with choosing high performance, disease-resistant seed varieties well suited for your growing conditions, followed by adequate fertilization, proper control of weeds, insects, and diseases. Timely harvest at the correct stage of growth and proper storage are further requirements for obtaining and maintaining high quality yields and maintaining

FIGURE 1-3

Relative cost of nutrients for common livestock feedstuffs in the U.S.

Feedstuff	As Fed Ton	Mcal of Energy	Lb of NDF (fiber)	Lb of Protein
Alfalfa *(average quality)*	$135.00	$0.084	$0.178	$0.389
Corn Silage *(normal)*	$32.00	$0.043	$0.101	$0.518
Corn grain *(dry ground)*	$140.00	$0.056	$0.836	$0.845
Whole Cottonseed *(linted)*	$275.00	$0.116	$0.303	$0.649
Soybean Meal *(48% CP)*	$335.00	$0.121	$1.910	$0.348

FIGURE 1-4

Hay acreage and yields in the U.S. since 1979

Year	Total acres harvested, 1,000s	Yield per acre harvested, tons
2009	59755	2.47
2008	60152	2.43
2007	61006	2.41
2006	60632	2.32
2005	61637	2.44
2004	61944	2.55
2003	63371	2.48
2002	63942	2.34
2001	63516	2.46
2000	60355	2.54
1999	63181	2.53
1998	60006	2.52
1997	61084	2.5
1996	61169	2.45
1995	59764	2.58
1994	58815	2.55
1993	59689	2.46
1992	58903	2.49
1991	61834	2.46
1990	61030	2.4
1989	62722	2.31
1988	64771	1.94
1987	60133	2.45
1986	62334	2.49
1985	60461	2.46
1984	61414	2.45
1983	59694	2.36
1982	59812	2.5
1981	59599	2.39
1980	58870	2.22
1979	61279	2.4

stands. Finally, proper feeding or marketing is vital to provide optimal profitability from the production of hay.

Focus on Forage Quality

Today's hay markets with few exceptions are no longer interested in "roughage," which as defined by *Webster's Dictionary* as "coarse bulky food that is relatively high in fiber and low in digestible nutrients and that by its bulk stimulates peristalsis." Hay markets have evolved to value the quality of the forage being sold. Forage quality is the combination of nutrient density and digestibility. On a nutrient basis, 4.5 pounds of good quality alfalfa delivers roughly the same amount of digestible nutrients as 3 pounds of corn grain. And, on a protein basis, high quality grass and alfalfa hays have approximately two and three times greater concentrations than corn.

Least Expensive Feed

Costwise, hay has always been one of the least expensive sources of feed for livestock. *And it can be as high in feeding value as many concentrates*. However, hay production frequently varies in quality more than any other North American agricultural products. Protein and other nutrient losses that occur after hay is cut frequently amount to 30% or more. Research has shown that, with new production varieties and preservation methods, much of this loss can be prevented.

Producers and Researchers Face Challenges

With a constantly shrinking land base due to urban sprawl and competition for existing tillable acres from the major field crops of corn and soybeans, producers and researchers face several challenges going forward:

1. Increase hay yields per acre on both irrigated and non-irrigated ground.
2. Improve plant genetics and traits for increased forage quality.
3. Develop and implement new harvest technologies to reduce losses and preserve forage quality.
4. Incorporate labor saving systems into all phases of hay harvest and storage.
5. Improve methods for measuring the feeding value of hay.

Harvesting Practices

First, let's establish the primary objectives of tomorrow's hay and forage harvesting systems. Early and frequent harvest are the two most important factors affecting quality. And, undoubtedly, every hay and forage producer wants a system that: (1) minimizes the weather risk for lower field losses, (2) has higher quality by rapidly reducing moisture in the field to a safe storage level, (3) conserves all possible leaves and green color, (4) reduces the man-hours necessary to handle the crop, and (5) includes machines that are cost effective, reliable, desirable, durable, and safe.

A fairly recent method that has been rapidly adopted across the U.S. is wide-swathing. The concept is to create as wide a swath as possible coming from the mower-conditioner to expose as much of the crop to sunlight as possible so that plant stomates remain open to allow moisture to escape, decreasing drying time. Using a combination of wide-swathing and other drying/preservation techniques has made “hay in a day” possible in more humid conditions.

Another recent method under study to reduce field drying time is to severely crush the crop until cells are broken and the water within the plant is exposed.

This process, known as maceration, has proven effective. However, the crop loses its structural integrity and becomes very difficult to package after drying and is more vulnerable to rain damage. There are still problems, but maceration will continue to be studied, seeking the solution to rapid drying with low field losses during packaging.

According to the 2007 Ag Census, approximately 91% of all hay crops are baled as dry hay with the remainder harvested as haycrop silage. While baling dry hay will continue to be the predominant method of packaging, other methods are used by some producers, and considerable research is ongoing in packaging and handling systems.

Use of forced air, either heated or unheated, for final drying gives the most dependable returns in quality. Still, this practice is on the decline in the U.S. most likely due to the cost. Heating the forced air adds to drying costs. However, application of heat does provide additional advantages such as faster drying, increased saving of leaves, and reduced losses of nutrients.

Hay is a more important feed source of energy for dairy cattle than for any other farm animal. (Photo courtesy www.ruralni.gov.uk)

Handling Hay

Machines that have been developed for handling hay include the mower-conditioner and windrower, bale thrower, self-propelled automatic bale wagon, large round baler, large square baler, and wafering or cubing machines. With this equipment, productivity per man-hour doubled between the two periods 1945-49 and 1960-64, and with the use of automatic bale wagons and large hay package systems, the productivity level today has more than doubled again from the 1964 level.

Research to improve haymaking has evolved over the past decade to focus on increasing density of hay bales, retention of leaves, pre-cutting hay-crop to facilitate diet-mixing and feeding, facilitating proper particle size, and increased throughput of machines.

Measuring Feed Value

Hay has high nutritive value if it is high in digestible dry matter (DDM) or estimated net energy (ENE), high in digestible protein, low in acid detergent fiber (ADF), high in palatability and relatively low in weeds or other foreign matter.

Wet chemistry analysis has been used to predict the nutritive value of forages and is still the "gold standard" among most state, university, and private testing laboratories. However, Near Infrared Reflective Spectroscopy (NIRS) has become the accepted method for measuring quality in many labs across the U.S. and throughout the world.

The most common analyses for hay crop forages include dry matter (DM), crude protein (CP), heat-damaged CP, acid detergent fiber (ADF), and neutral detergent fiber (NDF) along with mineral analyses. Over the past decade, analysis for sugars and neutral detergent soluble carbohydrates has become of great interest as the feeding requirements for dairy cattle have been further refined.

The methods to evaluate the quality of a forage have evolved to include in-vitro digestibility measurements. The traditional Tilley and Terry procedure from the 1970's has been improved and refined to increase repeatability. The information provided is now combined with levels of ADF and NDF to determine the energy available from a variety of forages.

Marketing Hay

Marketing hay, especially alfalfa, through commercial channels is an important agribusiness across the U.S. Quality standards have been put into place to increase transparency in many hay markets by improving the consistency of products delivered. These standards have included CP, ADF, NDF and Relative Feed Value (RFV), which is a formula-based value that assesses relative quality among similar hays. Recently, RFV has been surpassed by Relative Forage Quality (RFQ), which combines the levels and digestibility of fiber in forages to compare potential energy availability. These forage quality standards, especially the alfalfa standards, have come about from the efforts of the

Management makes the difference in hay quality. The left sample is a leafy, palatable, high-energy forage that packs on gains and boosts milk production. The right sample, a result of poor management, is coarse, stemmy, unpalatable and low in nutrient content.

American Forage and Grassland Council (AFGC) (www.afgc.org) and other organizations. These industry organizations continue to work together to improve the hay markets in the U.S. and abroad.

Hay As A Cash Crop

Historically, most of our hay has been fed on farms where it was produced, but times have changed. Today a substantial percentage of the annual U.S. production is sold off the farm. There are, of course, many factors that can affect year-to-year movement of hay, and thus profitability in the marketplace. These include such things as pasture and range conditions, local weather conditions, available grain supplies, and cattle, sheep, and horse numbers. Nevertheless, hay, and especially alfalfa hay, is potentially one of the best cash crops available on many U.S. farms.

Who Buys Hay?

Markets have changed over the past decades. Traditionally, dairy and beef producers were the major buyers in many parts of the country (Figure 1-5). But, other hay markets continue to grow. The U.S. horse population, both race horses and pleasure horses, has been increasing steadily and currently stands at approximately 9.2 million. These animals require high quality, mold-free hay and most horse owners buy nearly all of their hay.

Mushroom growers in some areas are an important market for hay, too. They require highly digestible hay and/or straw as part of their substrate mixture for mushroom cultivation.

Pennsylvania is the top-producing mushroom state in the U.S., followed by California, Florida, and Michigan (Mushroom Industry Report, 94003, ERS/USDA). Moldy hay or straw is generally not a problem as the substrates are normally sterilized prior to use.

The export market continues to grow. This requires top-quality, weed-free hay and a special hay package-meal, pellets, cubes, or high-density bales. It's a multimillion dollar business and growing, with hay going to Japan, Europe, South America, the Caribbean, and many other areas. For example, in 2008, China purchased 20,000 metric tons of hay, and that increased to 100,000 metric tons in 2009.

How Is Hay Sold?

Visual inspection is still the most common method of assessing quality and price. The development of Near Infrared Reflectance Spectroscopy (NIRS) has led to another rapid, accurate, and precise method.

Radio-frequency bale identification tags or *CropID*™ tags permit identification of individual bales and contain the vital statistics of each. They are increasingly being used by modern hay buyers to validate quality, allowing the producer to demand a premium price.

The *CropID*™ system used with today's well equipped, modern, large square balers can document the date the bale was made, hay moisture levels when baled, hay preservative and inoculate levels, and even an accurate measure of bale weight.

Hay dealers or brokers are still major suppliers. In some areas more hay is being marketed through co-ops. Special computer-assisted marketing systems help growers find buyers and to help buyers locate hay. A privately owned National Hay Exchange Corporation, using a computerized system, allows people to trade hay much easier in much less time. But the big increase in marketing hay in many areas of the U.S. may be through hay auctions.

Check to see which of these marketing systems works best in your area:

Neighbor-to-Neighbor or Producer-to Consumer – This has been the traditional marketing method and is still quite common - even in major hay marketing states.

FIGURE 1-5

Livestock inventories in the U.S.

Animal Type	2000	2010
Beef Cows	33,950,000	31,375,900
Cattle on Feed	14,073,000	13,462,200
Sheep ***(including lambs)***	7,063,000	5,630,000
Milk Cows	9,182,800	9,080,500

Source: NASS/USDA.

Associations or Cooperatives – These can vary from very simple organizations with low inputs of capital and management, to very large organizations.

Hay Dealer or Broker – Hay is purchased from the producer by the dealer and sold to the consumer. The dealer or broker usually possesses the art of matching hay quality based on visual inspection with consumer preference. However, forage analysis as a means of estimating quality is gaining favor in some areas. It is estimated that 10% of the hay produced is marketed by dealers.

Auctions – As indicated earlier, this is probably the most rapidly growing method of marketing hay. Originally, as was true for the early Pennsylvania auctions, this method simply brought together the producer with loads of hay, an auctioneer, and an assembly of prospects. Hay was sold by visual inspection, and the price determined by supply and demand.

That approach is still used in many areas. In some areas, the number of hay auctions has increased substantially due to the introduction of NIRS equipment, usually in mobile units, as a rapid method of measuring hay quality prior to sale, plus the grading of hay according to test results.

The Agricultural Marketing Service branch of the USDA provides weekly reports on regional hay markets. These reports can be automatically e-mailed to you. Access to these reports can be found at http://www.ams.usda.gov/ under the Market News Section.

Contract – This method is an agreement between a producer and a buyer to supply hay of specified quality at a prior agreed price. Here again NIRS, as a method of estimating quality, is making inroads. A contract assures both buyer and seller an orderly market. Weather damage and other quality limiting factors need to be covered in the contract.

Pricing Hay

Traditionally, most hay was sold and bought using the ancient art of bartering. The dealer matched hay quality, based on his judgment, with consumer preference. A price was agreed on and the hay was sold.

Much hay is still bought and sold this way. But, again, the practice is changing. One of the fundamental hay marketing problems has always been one of determining price by some realistic measure of its feed value. That meant some type of forage analysis. Several states, mainly in the West, took the lead early on in selling alfalfa hay on the basis of quality as determined by analysis. In California, for example, for many years hay has been priced on an estimated total digestible nutrient (TDN) basis. This is a simple, quick test, based on modified crude fiber content. It also gives a measure of estimated net energy (ENE) as does TDN, but ENE is more accurate when comparing various classes of feeds. Its use is limited to pure alfalfa, but alfalfa is the primary hay crop grown and marketed in the West.

Another approach to pricing legume and grass hays has been the incorporation of a relative feed value (RFV) into the pricing scheme. This method uses the acid detergent fiber (ADF) and neutral detergent fiber (NDF) content of the hay to estimate the feeding value, and is valid on only pure stands of legumes or grasses. Over the past five years, RFV has been supplanted in the dairy industry by relative forage quality (RFQ), which accounts for both the content of fiber and the digestibility of the fiber. Both RFV and RFQ are used primarily in marketing hay and comparing seed varieties.

National Alfalfa Hay Quality Standards

Early on, the American Grassland Council developed standards which several states used in their hay marketing systems. But for various reasons these standards were not accepted by the Federal Grain Inspection Service and the hay industry.

Earlier efforts did, however, lead to the formation of the National Alfalfa Hay Quality Committee and the development of national alfalfa hay quality standards. Their intent is to have uniform testing throughout the U.S. so both seller and buyer can receive accurate and interpretable results on any given lot of hay. While these latest standards are based on a minimum test of alfalfa hay for dry matter, crude protein (CP), ADF, and estimated digestible dry matter (EDDM) calculated from the ADF, test provisions are also included for a description sheet of visual characteristics.

Procedures for the national alfalfa hay quality standards are carefully spelled out and include: (1) specific sampling procedures using an improved hay core sampler, (2) suggested visual factors to be used with chemical analysis to describe the sample, (3) approved testing procedures using either NIBS or wet chemistry, (4) development of an acceptance of Acid Detergent Fiber (ADF) to predict estimated digestible dry matter, and (5) a voluntary laboratory certification program operated by the National Alfalfa Hay Test Association in conjunction with AFGC and the National Hay Association.

While tremendous progress has been made in hay marketing, authorities feel other developments are still necessary to make hay even more attractive as a cash crop. These include:

(1) Establishing even more suitable markets such as auctions and dealers or associations that can provide a ready market for hay when the producer wishes to sell, providing an ample supply of hay to attract prospective buyers, and to give them a suitable choice of quality and quantity.

(2) A further market development to provide price protection for the dealer while he has possession of the hay, probably in the form of a futures market that will permit hedging protection.

(3) Producers should have adequate storage facilities that can spread the hay marketing over a longer period and avoid harvest peaks that usually depress price.

Growing

Planning Your Hay Program

As overhead and production costs continue to increase and more resources are included into many farm enterprises, careful planning becomes critical to help forage producers decide which crops to incorporate into their crop and livestock enterprises. In this regard there are several good reasons why hay belongs on many agricultural operations:

1. Forage is a high-profit crop when produced and/or fed efficiently.
2. Forage can offer a lower-cost source of high nutrient feed for ruminant livestock.
3. Forage is complementary to grain crops, resulting in higher total grain yields. (Forages in rotation reduce diseases and other pests, improve soil tilth, and in the case of legumes, add nitrogen to the soil).
4. Forage plays an important role in controlling erosion.

However, the acreage of hay and types of forages needed in any livestock operation depend on several factors. These include: (1) acreage and soil type limitations, (2) the number and type of livestock, (3) their feed requirements, (4) the yield potential per acre of the crop, and (5) your storage and feeding system.

Careful planning is critical to help forage producers decide which crops to incorporate into their crop and livestock enterprises. There are several good reasons why hay belongs in many agricultural programs.

The species of forage grown is determined by soil type, topography, climatic conditions, soil drainage, production and storage capacity, equipment availability, managerial ability, managerial preference and market demand. The livestock farmer should be interested in obtaining the maximum feed supply at the least total cost, along with land use practices that will maintain the productivity of the land.

To complete the picture, producers need to know the quality of their forage in terms of total digestible nutrients and protein. That requires using forage analysis.

First Step to Hay Profits

Now, let's look at hay itself. The first step in growing hay profitably is to treat it as a money maker – not a sideline. Higher forage yields greatly increase profits since per unit cost of production will be lowered. The cost of mowing, raking and baling forages is basically the same for each pass over an acre of forage. When a cutting of 2 to 3 tons of hay is harvested per cutting per acre, the cost per ton will be significantly less than when producing ¾ or 1 ton per acre.

Scientific Crop Programming

The most profitable cropping system on any farm depends on the "production relationship" between crops in rotation, according to farm management specialists. Crops can have at least three different relationships: (1) competitive, (2) complementary, and (3) supplementary.

Competitive Crops. If crops compete, such as alfalfa and clover, boosting production of one results in a decrease in acreage and production of another. Crops can compete at constant or increasing rates.

When crops compete at constant rates, growing more acres of one means giving up a fixed amount of the other. Say, for example, clover yields 4 tons per acre and alfalfa 6 tons. Then, where adapted, seeding an acre to alfalfa means giving up 4 tons clover and gaining 6 tons alfalfa.

It seldom pays to grow two crops that compete at constant rates. Decide which crop is more profitable per acre based on accurate crop production records and concentrate on that crop.

When crops compete at increasing rates, growing one affects the yield of the second. An example is alfalfa and grain in different rotations. Say, for example, by going from continuous corn to a 5-year rotation of corn-corn-corn-oats-hay, each ton of hay gained can mean losing 7.5 bushels grain; going to hay alone, 20.4 bushels. In this case, the sacrifice increases when shifting from grain to hay. Usually it pays to grow a combination of crops rather concentrate on just one.

Complementary Crops. Crops are complementary when growing one in rotation boosts yields of another. For example, legumes in rotation add nitrogen to the soil, while grasses as well as legumes control erosion, reduce diseases and pests, and improve soil tilth – resulting in higher grain crop yields.

In the short run – about one to three years – most crops are competitive, specialists say. However, hay crops are generally complementary to grain or other crops over a number of years.

Supplementary Crops. Crops are supplementary when one can be added to the rotation without changing production of another. The most common example is small grains used as a companion crop to help control weeds while establishing seedings. However, chemical weed control in new seedings might be a better choice if there is little need for a second crop, or if the companion crop reduces materially the yield of the primary crop.

Harvesting, Storing, Feeding

You've got to consider other costs, too, when planning your total forage program, including harvesting, storing, and feeding methods.

There's no doubt that high yields demand special attention to harvesting and storage practices which save both maximum feed and dollars. Most economic studies indicate that when all factors – field and storage losses, labor and machinery requirements, and all related costs – are considered, the net value of nutrients produced per acre is about the same, whether the crop is harvested as hay or wilted hay crop silage.

From a feeding standpoint, there is little difference between feeding forage either as hay or haylage alone or in both forms simultaneously, if quality is maintained.

Though silage sometimes adapts better to mechanized feeding systems, baled hay can compete when it comes to feeding time too. The key is to keep hay as close to livestock as possible. With baled hay near the point of consumption, feeding time on a dry matter basis can actually be less than with many commonly used mechanical haylage systems.

Choosing a Cropping System

Now that you've taken a look at many of the factors involved in planning your hay program, how can you choose a forage program that will best meet livestock needs and maximize profits?

To begin with, a cropping system combines crops that yield the most net income over the long term. To maximize net income, carefully consider a system and then stay with it.

Too often a producer jumps from one production enterprise to a completely new one. Designing and developing a consistent system gives a farmer an opportunity to make each enterprise more efficient.

Since forages and grain are complementary over the long run, farm management specialists say producers generally receive greater total net income from a cropping system with hay crops that also increase grain production.

However, there are other factors to consider besides crop compatibility. Climate and soil also determine which forages can be grown and their yield potential. Land too hilly for row crops, for example, is naturally suited for forages that control erosion. Besides hilly land, a short growing season in northern areas may make it impossible to produce profitable row crop or grain yields. In this case, it might pay to seed more forages and increase your livestock program to utilize the extra hay.

FIGURE 2-1

Production Costs, Cost per Ton, and Net Returns at Various Yield Levels; Pennsylvania Alfalfa Growers Program (1981-84)

Yield Range Tons/Acre	Ave. Yield Tons/Acre	Production Cost per Acre	Cost per Net Ton	Net Return per Acre
< 3.01	2.76	$279.73	$104.25	$(59.60)
3.0 - 3.9	3.5	$255.47	$75.91	$16.51
4.0 - 4.9	4.55	$250.05	$56.80	$94.33
5.0 - 5.9	5.51	$285.36	$53.88	$138.46
6.0 - 6.9	6.44	$304.19	$49.25	$196.50
7.0 - 7.9	7.34	$310.46	$43.74	$258.87
> 8.0	8.13	$344.20	$43.95	$310.21

(1) ave of 1983 & 1984 only

FIGURE 2-2

Crop Alternative Budget Summary for Selected Crops, Acre Basis for Livestock Farmer

Item:	Shelled Corn	Corn Silage	Alfalfa Hay	Clover-Grass	Soybeans
1. Yield per acre*	105 bu.	18 tons	4.5 tons	2.8 tons	35 bu.
2. Unit Value **	$2.45	$23.00	$70.00	$63.00	$5.00
3. Acre Value (1x2)	$257.25	$414.00	$315.00	$176.40	$175.00
Cost:					
4. Fertilizer, Lime, Spray, & Seed	$98.00	$98.00	$57.00	$40.00	$39.00
5. Machines, drying, grinding grain	$42.00	$18.00	$16.00	$14.00	$16.00
6. Labor ($3.00 per hour)	$18.00	$36.00	$24.00	$21.00	$18.00
7. Total costs (4+5+6)	$158.00	$152.00	$97.00	$75.00	$73.00
8. Margin over costs (3-8)	$99.25	$262.00	$218.00	$101.40	$102.00

* Out of storage.

** Comparative values of crops when shelled corn is $2.45 per bushel and soybean meal is $203 per ton; Peterson method. Based on commodity prices in Pennsylvania in 1985.

Since forages and grain crops are complementary over the long run, specialists say you generally get more total net income from your cropping system with hay crops that also boost grain production.

CHAPTER 3

Match Crop to Soil

Bringing your hay profit picture into focus begins with matching your crops to your soils. It isn't possible to discuss all the perennial hay species, nor all the possible soil conditions, in this handbook. But wherever you live, sit down with your local agriculture authorities to work out the best crop-soil match for your farm.

Start with Soil

Let's start with the soil itself. Soils vary widely in acidity, fertility, topography, depth, and drainage. In most sections of the country, single fields frequently contain not just one, but several soil types.

You can improve many soil conditions, such as reducing acidity, by proper liming and supplying ample plant food by proper fertilization. These factors will be discussed in more detail in later chapters.

You can also often correct a drainage problem by tile or ditch drainage. This type of soil improvement usually results in higher yields, easier field working conditions and longer-lived stands of perennial crops.

You can also improve the poor physical condition of some soils by following sound soil improvement practices.

Wherever you live, sit down with your local agriculture authorities to work out the best crop-soil match for your farm, starting with the soil itself.

This includes incorporating animal manures, where available, to add organic matter and to increase soil fertility levels.

Tolerance to Poor Drainage

Agronomists know that many forage species vary in their tolerance to soil depth and drainage. Yet producers frequently attempt to establish a species on a soil where it is not suited. Figure 3-1 provides an idea as to how various species compare in their tolerance of soil drainage.

Of course, species such as bird's-foot trefoil and reed canary grass also grow well on deep, well-drained soils. But producers are increasing their risks when they attempt to grow a species not tolerant to poor drainage, such as alfalfa, on poorly drained soil.

Plant breeders have given you an assist too. Each year producers have access to more and more improved varieties within each forage species. Many newer varieties now have special characteristics which may make them better adapted than older varieties to a given soil, such as type of root system or resistance to certain soil-borne diseases peculiar to wetter soils.

Commercial and public plant breeders continue to search for new forage crops that are better adapted to the shallow, acid, infertile, or even saline soils common to many areas of the country and the world. This is another approach to matching the crop to the soil.

Today, university and commercial forage trials provide producers with the latest information on forage yields, growth characteristics, and long-term stand survival traits. This information is available through many university extension trials on the internet and provides decision making guidance for local growing situations.

Producers should insist on high-quality seed of these improved named varieties. Quality seed will be discussed in detail in a later chapter.

Figure 3-2 summarizes the adaptation and use of a large number of species grown for forage. We will be referring back to this in later chapters.

FIGURE 3-1

Tolerates Moderately Poor Drainage	Tolerates Slightly Poor Drainage	Very Sensitive To Wet Soils
Bird's-foot Trefoil	Red Clover	Alfalfa
Ladino Clover	Kentucky Bluegrass	Crownvetch
Alsike Clover	Perennial Ryegrass	Bromegrass
Reed Canary grass	Orchardgrass	
Tall Fescue	Timothy	
Switchgrass	Brassica Sp.	
Big Bluestem	Sudangrass	

Incorporating manure into the soil adds organic matter, stabilizes the soil, and retards runoff. New manure testing techniques enable you to get a better idea how much manure to apply.

FIGURE 3-2A

Adaptation and use of various species grown for forage (Legumes)

	Legumes				
Species	**Alfalfa**	**Red Clover**	**Bird's-foot trefoil**	**Lading clover**	**Alsike Clover**
Est. Stand Life *(Years)*	3-5	1-2	2-3	1-2	1-2
Approx. Yield *(tons/acre)*	4-7	3.5-5	2.5-4	1-2	1-2
Soil Adaption	Deep, well drained	Medium to well drained	Somewhat poorly to well drained	Poorly to well drained	Wet, acid soils
Recommended soil pH	6.0 +	6.0 +	6.0 +	6.0 +	6.0 +
Seeding Aggressiveness *(1 most - 6 least)*	2	1	5	3	2
Forage Management	Hay, Silage, Pasture	Hay, Silage, Pasture	Hay, Silage, Pasture	Pasture, Silage	Pasture, Silage, Hay
Pasture Management	Rotational	Rotational	Continuous	Rotational	Rotational
Bloat Potential	More Intense	Intense	None	Potential	Potential

Preferred Species Mixture	
Alfalfa	Tall, cool season grasses and Perennial Ryegrass
Red Clover	Bluegrass, Tall Fescue
Bird's-foot Trefoil	KY Bluegrass, Perennial Ryegrass, Reed Canary Grass
Lading clover	Any cool season grass, except Timothy(Climax), and smooth Bromegrass
Alsike Clover	Red clover

FIGURE 3-2B

Adaptation and use of various species grown for forage (Cool Season Grasses)

Species	Kentucky Bluegrass	Perennial Ryegrass	Orchard grass	Smooth Bromegrass	Timothy (Climax)	Reed Canary grass	Tall Fescue
	Cool Season Grasses						
Est. Stand Life *(Years)*	4+	3-4	3+	3+	3+	3+	3+
Approx. Yield *(tons/acre)*	2.5-3	2.5-4	3.5-5	3-4.5	3.5-4	3.5-6	3.5-5
Soil Adaption	Medium to well drained	Moist to well drained	Moist to well drained	Fertile well drained	Medium to well drained	Widely Adapted *(Wet/Dry)*	Widely Adapted *(Shallow/Deep)*
Recommended soil pH	6.0+	6.0+	6.0+	6.0+	6.0+	5.5+	5.5+
Seeding Aggressiveness *(1 most - 6 least)*	6	1	2	3	4	5	3
Forage Management	Pasture	Pasture, Silage, Hay	Pasture, Silage, Hay	Hay, Silage, Pasture	Hay, Silage, Pasture	Pasture, Silage, Hay	Pasture, Silage, Hay
Pasture Management	Rotational	Rotational	Rotational	Rotational	Rotational	Rotational	Rotational

Preferred Species Mixture

Kentucky Bluegrass	Bird's-foot Trefoil	Lading clover		
Perennial Ryegrass	Alfalfa	Bird's-foot Trefoil	Lading clover	
Orchard grass	Alfalfa	Lading clover		
Smooth Bromegrass	Alfalfa	Red Clover	Bird's-foot trefoil	Lading clover
Timothy (Climax)	Alfalfa	Red Clover	Bird's-foot trefoil	
Reed Canary grass	Alfalfa	Lading Clover		
Tall Fescue	Alfalfa	Red Clover	Lading clover	

FIGURE 3-2C

Adaptation and use of various species grown for forage (Warm Season Grasses) (Other Grasses)

Species	Switchgrass	Big Bluestem	Bermuda grass	Brassicas *(Rape, Kale, Turnips, Swedes)*	Sudan grass
	Warm Season Grasses			Other Grasses	
Est. Stand Life (Years)	4+	4+	4+	4 months	4 months
Approx. Yield (tons/acre)	5-6	4-5	5-8	3-6	3-5
Soil Adaption	Somewhat dry to poorly drained Tolerant to low fertility		Moderate to well drained, & Heavy soils	Moderate to well drained	Moderate to well drained
Recommended soil pH	-	-	5.5+	5.5+	6.0+
Seeding Aggressiveness *(1 most - 6 least)*	6	6	6 *(by sprigs)*	4	1
Forage Management	Pasture, Hay	Pasture, Hay	Intensive pasture, green chop	Pasture, Silage	Pasture, Silage
Pasture Management	Rotational	Rotational	Rotational	Rotational or Strip Grazing	Rotational or strip Grazing, and Green chop

Preferred Species Mixture

Switchgrass	NONE
Big Bluestem	NONE
Bermuda grass	NONE, Crimson or Arrow leaf Clover
Brassicas *(Rape, Kale, Turnips, Swedes)*	NONE
Sudan grass	NONE

CHAPTER 4

Growing

Lime – A Must for Quality Hay

It has been said that if the 100 most learned scientists in the world were locked in a room and told to list, in order of priority, the things man must do to continue to live on this earth, liming of the soil would certainly be one of the top ten.

Scientists throughout the world agree that acid soils "hold back" forage profits unless corrected with lime additions. Dr. S. R. Aldrich, former Illinois agronomist, summed it up this way, "On medium to strongly acid soil, few, if any investments give as much return per dollar as limestone."

Liming Pays Big Dividends

When needed, lime is a big crop booster that leads to equally big hay profits. Liming is the first step in creating favorable soil conditions for productive plant growth. Lime is so important that agronomists consider it just as important as nitrogen, phosphorus, and potassium in the profitable production of all plants. One thing is certain: liming acid soils is an absolute must for high forage yields and profit!

Just how much increased yield and profit you can expect from liming depends on several things, such as the crop grown and its sensitivity to acidity, and the amount of lime needed in relationship to other production costs.

But it's the key. Soil pH greatly affects the availability of most other soil nutrients. At low pH levels the majority of

When needed, lime is a big crop booster that leads to equally big hay profits. Liming is the first step in creating favorable soil conditions for productive plant growth.

soil phosphorous and potassium becomes unavailable to plant root uptake. These nutrients become bound up in the soil complex.

Soil Test – The Only Way to Know

Before we take a critical look at lime itself, let's establish one important fact. As valuable as lime is, the only way to know how much and what type of limestone to apply is by taking a soil test.

Remember, however, soils often vary widely within a field, either naturally or as a result of previous management. That's why it's so important to take a representative soil sample.

There are several ways that soil samples can be taken. But if you follow the 11-step procedure suggested here, you're on the right track:

1. *Get full information* from your fertilizer dealer, county agent or other agriculture worker on how to take a sample. Soil sampling procedures vary, so study instructions before taking samples.
2. *Use the right sampling tools*. The best is a soil probe or auger, or you can use a garden spade or shovel. Fertilizer dealers and county agriculture workers often have these probes for loan. Use a paper bag or clean plastic bucket for collecting soil samples in the field. Metal or dirty buckets can contaminate soil samples.
3. *Avoid unusual areas*. Try to stay away from dead furrows, back furrows, terrace channels, windbreaks and old fence lines, old storage sites of manure or lime, wet spots, and areas near limerock roads or tree lines.
4. *Divide fields into sampling areas*. Usually each soil sample should represent no more than 10 to 20 acres if sampled properly. Sample each area separately that is large enough to be treated separately, if it differs in cropping, soil, or past management.
5. *Make up a composite sample* from each area. A composite sample is made of subsamples from 15 to 20 spots within the area to be tested. Sample soil to plow depth – 6 to 7 inches. (Soils for permanent forage crops receiving maintenance fertilization may be sampled to a 2- or 3-inch depth). Where crops were planted, sample between rows if row fertilization has been recent.
6. *When a shovel is used,* scrape surface litter and remove one shovel full to sampling depth. Cut a clean slice of soil about one-half-inch thick from the face of the hole. Then trim away soil on each side of the shovel, leaving a one-inch strip of soil for the sample.
7. *Mix composite samples* well before filling soil test bag for lab submission. Be sure the container is clean paper or plastic. Use about one-half to one pint of soil.
8. *Fill out information sheets* provided with the sample kit. Previous cropping history of sampled fields and statement of your yield goals are essential. This information, as well as soil test analysis, is used for accurate fertilizer and lime recommendations.
9. *Number and record soil samples*. Keep a numerical list of samples sent to the lab keyed to the field map of area(s) sampled.

10. *Follow recommendations* provided by the soil testing laboratory and keep records. Study your soil test recommendations carefully. Discuss them with your fertilizer representative. Be sure to review your management practices and crop yield goals. Make soil tests a part of your field records. By sampling soils every three years and maintaining fertility records you will be able to monitor soil fertility levels to attain optimum soil fertility levels.

11. *Samples should be submitted to soil testing labs* located close to your operation. Because soil conditions and chemistry vary across the United States, the local soil testing laboratories use specific buffering compounds to obtain more accurate test results. In addition, fertility additions are based on local soil conditions and crop production practices.

What Causes Soil Acidity?

Now let's get back to the matter of lime itself and ask ourselves "what causes soil acidity?"

Almost without exception where the average rainfall is more than about 25 inches per year, soils become naturally acid. When rainwater leaches through the soil it removes many soil elements and the soil becomes acid, no matter if limestone itself is the parent rock from which the soil is formed. And sometimes the rainwater itself has a high level of acidity, i.e. acid rain. In addition, acids are formed when crop residues and soil organic matter decay in the soil.

Manure, ammonium sulphate, anhydrous ammonia, urea, ammonium phosphates and urea-ammonium nitrate solutions acidify the soil. Soils require about 3 pounds of lime to neutralize one pound of N supplied by most of these fertilizers. Ammonium sulphate requires greater limestone additions to neutralize its acidifying affect due to the ammonium and the sulphur compounds. It takes 6 pounds of lime to neutralize the acidity of one pound of N supplied by ammonium sulfate.

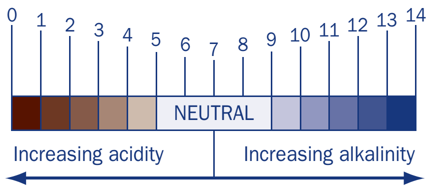
How Liming Corrects Acidity

Acidity is caused by the presence of hydrogen (H) ions; pH is a measurement of the activity of these H ions. The measurement scale covers a range from 0 to 14. A pH of 7.0 means the soil is neutral; pH values below 7.0 are acid. Those above 7.0 are alkaline (see pH scale, Figure 4-1).

When limestone is mixed with soil, the acids in the soil are neutralized by the action of the limestone, raising the pH. Although calcium and magnesium are important components of limestone, they do not change the pH. It is the carbonates that neutralize acidity. Thus, adding a calcium material like gypsum, which is calcium sulfate, will not change the pH.

FIGURE 4-1

pH SCALE



Crop Tolerance to Soil Acidity

Crops in general have different pH requirements for optimum growth. As indicated in Figure 4-2, forages and other crops can be grouped according to their tolerance to soil acidity.

You can successfully move a species up the scale, i.e. from moderate acidity to slight acidity or above. In fact, most forage species grow best when the soil pH is near 7.0. And most legumes, especially alfalfa, need a nearly neutral soil to promote growth of nodule-forming bacteria.

Crop Benefit from Liming

We've already indicated that liming acid soils increases the availability of nitrogen, phosphorus, potassium and many other plant nutrients. But lime also improves forage yields and quality in many other ways. Lime:

1. Reduces or prevents the toxic effects of iron, manganese and aluminum. These elements are found in strongly acid soils in amounts large enough to be toxic – especially to alfalfa and clover.

2. Resupplies both calcium and magnesium removed by crops and leaching.

3. Improves soil conditions for microorganisms. These tiny soil organisms speed decay plant residues, releasing more nitrogen and phosphorus for plants when pH is near neutral.

4. Enhances the formation and growth of nodule-forming legume bacteria. These bacteria (called rhizobia) take nitrogen from the soil air complex and make it available to plants.

5. Has a beneficial effect on soil structure.

6. Increases effectiveness of some key herbicides.

Kinds of Lime

In agriculture, the word "lime" has come to mean any material that is put on the soil to neutralize acidity. Over 95% of the "lime" used in the U.S. is ground limestone. The remainder is burnt lime, slaked or hydrated lime, marl, ground oyster shells, or slag.

FIGURE 4-2

Tolerates Moderate Acidity *(pH 5.5 to 6.0)*	Tolerates Slight Acidity *(pH 6.0 to 6.5)*	Very Sensitive *(pH 6.5 to 7.0)*
Bird's-foot Trefoil	Red Clover	Alfalfa
Reed Canary grass	Alsike Clover	Sweet Clover
Tall Fescue	Ladino Clover	Barley
Redtop	Timothy	
Bentgrass	Bromegrass	
Sudan grass	Orchard grass	
Millet	Kentucky Bluegrass	
Rye, Oats	Perennial Ryegrass	
Bermuda grass	Corn	
	Wheat	
	Bird's-foot Trefoil	

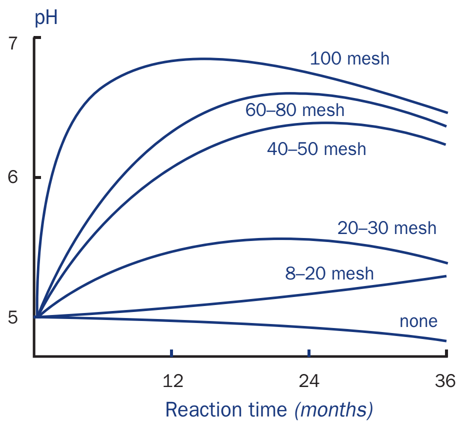
Today in some areas, liquid lime, i.e. finely ground limestone in a liquid suspension, is also available. It spreads and distributes more evenly than ground limestone but is usually too expensive for hay crops.

You may also hear about other products promoted as ag lime substitutes. Beware of these. They usually have little liming value, and some by-product materials may actually be harmful to the soil. If using any lime or fertilizer substitute, accurate and frequent soil sampling and the use of production analysis becomes very important. It is very possible that incorrect soil fertility additions can be made and can result in poor production and long term soil fertility correction challenges.

Size of Lime Particles Important

There are many types of ground limestone, differing mainly in the relative amounts of calcium and magnesium carbonates that they contain, the fineness to which they are ground, their neutralizing power, and the amounts of impurities in them.

FIGURE 4-3



These are the main points to look for when buying limestone.

Fineness: Since limestone dissolves slowly in water and moves very little in the soil, finely ground particles can be mixed more thoroughly with the soil and react faster than larger particles. As indicated in Figure 4-3, medium and large size particles combat acidity more slowly, but have some value since they raise pH over a longer period of time.

While standards for fineness vary, the following minimums would be for high-quality product:

- 95% through a 20-mesh screen
- 60% through a 60-mesh screen
- 50% through a 100-mesh screen

Neutralizing Power: This term simply refers to limestone's ability to neutralize soil acidity – referred to as the calcium carbonate equivalent (CCE). The greater the CCE, the more neutralizing power the limestone has. Soil test recommendations are usually based on a CCE of 100. Therefore, when using a material that is not 100 CCE, the recommendation must be adjusted. For example, a limestone with a CCE of 80 would require using more lime than a lime with a CCE of 110.

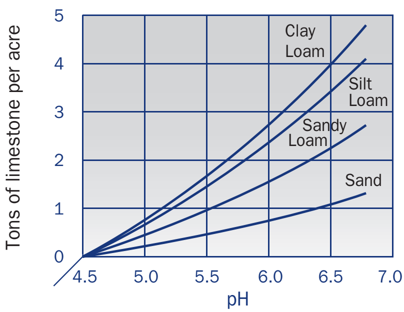
If your soil is low in available magnesium, then dolomitic limestone is the preferred lime to use. Dolomitic lime will supply magnesium in addition to neutralizing the soil acidity. If they are of equal purity and fineness, a ton of dolomitic stone will neutralize slightly more acidity than a ton of high-calcium stone.

Soil Types Affect Lime Needs

Even in the same field, different soil types with the same pH may need different amounts of lime to correct an acid problem (Figure 4-4). Fine-textured soils, high in organic matter and clay content, hold hydrogen ions tightly and need more lime to raise pH to the same level as coarse-textured soils. That's why soil tests are the best guide for both lime and fertilizer.

FIGURE 4-4

Limestone Requirements for Different Soils



Source: USDA Farmers' Bulletin No. 2124. "Liming Soils."

When Do You Apply Lime?

You can lime at many different times in the cropping system. Agronomists agree that since limestone works slowly in the soil, it's best to apply lime 6 months to a year before seeding legumes.

If there is sufficient time for an adequate reaction with the entire plow layer, at least one-half of the recommended lime rates should be added to the surface and disked in before seeding.

When four or more tons are needed, split the application by plowing one-half down and disking the remainder into the surface. Smaller applications needed to maintain a desirable pH can be made any time before seeding, applied either to the surface or plowed down.

But, whenever possible, it's best to apply the lime in the fall, especially to sods. At that time the soil is firm, and lime can be applied with less likelihood of machinery getting stuck and rutting and compacting the soil.

Liming for no-tillage production presents special problems. Often under no-tillage, the top inch of soil becomes acid more rapidly than the original plow layer. Thus, determining the pH and lime recommendations for no-tillage requires a special soil test procedure. When sampling no till fields, a separate sample should be taken from the top 2 inch level and submitted for analysis.

When to Re-Lime

How often a field needs to be limed or re-limed is best determined by a soil test. Guidelines have been set up based on widespread studies. Soil scientists estimate that from 400 to 600 pounds of lime are necessary per acre each year under normal cropping conditions in many crop producing areas.

Following a nation-wide survey, USDA researchers found that soils in the midwestern states generally require from 2 to 4 tons per acre at 5- to 10-year intervals, mid-south states 1 to 3 tons every 2 to 5 years, and the southern and southeastern states 1 to 2 tons every 3 to 5 years. A general recommendation for mid-Atlantic and northeastern states would be 1 ton of lime every 2 years. All applications should be based on actual soil tests and crops to be planted. Application rates are based on use of lime to maintain optimum soil pH levels, not to correct major deficiencies.

Saline and Sodic Soils – Special Problems

While low pH needs to be corrected in some areas, saline and sodic (high sodium) soils with high pH also reduce forage yields and profits. In arid areas, excess salts form in poorly drained soils. Capillary action, like the action of a wick, move soil nutrients (salts) upward in the soil with the water. If the water table is high (5 to 6 feet below soil surface), considerable capillary movement may occur, especially in medium and fine-textured soils.

As plants take up water, or as water evaporates, salts concentrate in the root zone or at the soil surface. Depending on the type of salt formed, soils become either saline or sodic.

Correcting Saline Soils

Saline soils have a high level of neutral salts and pH usually between 7.3 and 8.5. They are often called "white alkie" soils because white crusts usually form on the surface.

Improving drainage to keep water tables below a 5-foot depth is the real key to correcting saline soils. This allows leaching of salts from the upper soil. Leaching soils with irrigation water gives temporary relief, but water and salts move upward after leaching if the water table is high.

Producers cannot completely correct strongly saline soils under dryland conditions, but can often seed salt-tolerant species (see Figure 4-5). To produce the highest quality hay possible, use a mixture of moderate and high salt-tolerant forages. Even in the same field, salt content often varies enough to support less tolerant grasses that usually make better quality hay.

Moderately tolerant forages grow in early spring before soils dry out and salt injury becomes a problem. If moisture conditions favor growth late in the season, these forages recover from salt injury. Producers still can get some yield even if injury is severe.

Authorities also recommend growing deep-rooted, high water-using forages where possible. Deep growing roots pick up some capillary water, reducing salt build-up at the soil surface or in the root zone. They also deplete moisture deep enough to let some melt and rainfall flush surface salts into subsoil.

Figure 4-5, compiled by USDA researchers at Maudan, North Dakota, lists salt tolerance of several forage crops for both saline and sodic soils.

Recently, C. W. Robbins, a USDA soil scientist working in Idaho, discovered that the annual sorghum x Sudan grass hybrid may have a special place on salt-laden soils in the West. Robbins found that this grass releases a high level of CO_2 in the soil, which in turn frees the sodium so rainfall or irrigation water can leach out sodium normally bound up in the soil. The cleansing takes at least two growing seasons, according to Robbins, but his studies

FIGURE 4-5

Salt Tolerance of Various Forages for Saline & Sodic Soils

Tolerance Level	Forage
Most Tolerant	Canada wildrye, wheatgrass (tall, western, slender & crested) & Russian wildrye
Moderately Tolerant	Bird's-foot trefoil, sweet clover, alfalfa *(established)*. Reed canary grass, smooth bromegrass
Moderate to Low Tolerance	Sorghum, alfalfa *(young)*
Low Tolerance	Clover *(White Dutch, alsike, red & ladino)*

Data: USDA

indicate that the grass could be used to reclaim millions of acres of salt-bound soils in arid western states, parts of the Northern Great Plains, western Canada, and similar areas of the world.

While the sorghum x Sudan grass hybrids are not normally grown for hay, they are highly productive and make an excellent silage for livestock.

In areas of arid southwest Arizona, scientists are looking for salt tolerant plants for use as forage with direct seawater irrigation. Several of the species being studied have high nutritional value and also have high digestibility, these scientists say.

Fertilizer, manure, and mulch also will help shape up saline soils. Excess salts keep roots from picking up nutrients readily, so spreading fertilizer can boost yields by supplying extra plant food. Best response to fertilizer often shows up during a dry year.

Chemical or commercial soil conditioners don't improve salty soils. In fact, they might make matters worse. Gypsum or sulfur, for example, may actually add more soluble salts to the soil.

Summer Fallow May Work

Generally, specialists say summer fallow won't help saline soils. However, USDA research doesn't completely agree. In North Dakota tests, summer fallow – where weeds were controlled and soil mulch maintained – reduced salt levels. Less than half the salts were in the top two feet of soil by the end of the second fallow season.

Salt levels were reduced by leaching of water remaining after evaporation. Undercropping, evaporation, and transpiration losses leave little or no excess water for leaching.

If the water table is high, however, it is best not to summer fallow. Fallow stores moisture in the soil, thus raising the water table. As a result, surface evaporation and salt concentration may increase. Also, run-off water may stay in low areas on the soil surface and this can cause the water table to rise.

Early Seeding Beats Salt Problems

Where leaching with irrigation water isn't possible, agronomists recommend seeding forages as early as possible. Lower evaporation rates and high rainfall cut chances of salt injury in early spring. Early seeding is especially important for alfalfa, which is only slightly salt tolerant in the seeding stage.

If you leach with irrigation water, a common rule of thumb is to apply a foot of water for each foot of soil to be leached, based on California research. Crop selection, of course, is still a key factor even where frequent leaching is possible.

In Nevada tests, researchers couldn't establish bird's-foot trefoil or strawberry clover, even by irrigating every 2 days for 8 weeks after seeding. Tall wheatgrass and tall fescue stands, however, took hold.

During the study, irrigating every two days during establishment resulted in highest yields and best stands for both grasses. Irrigating less often (at 4- and 8-day intervals) produced poorer stands and lower yields.

Correcting Sodic Soils

Soils high in sodium are technically called sodic. They are most commonly called "alkali" soils since many sodic soils are also alkaline. Soil color usually becomes darker. Sodic soils contain enough excess sodium salts, especially sodium bicarbonate and sodium carbonate, to raise pH above 8.5.

Shaping up sodic soils for forage production takes a slightly different approach than saline soils if you irrigate. While a deep drainage system is just as important for sodic soils, chemical amendments are a must for bringing them up to full potential.

CHAPTER 5

Fundamentals of Forage Fertilization

Fertilizer is, in the opinion of many experts, the most important single key to profitable hay yields. The bacteria in well-nodulated legumes almost always manufactures enough nitrogen from the air to supply their own needs.

Many years ago, Justus van Liebig developed his famous "Law of the Minimum." In brief, it states that the level of crop production can be no greater than that allowed by the most limiting of the essential plant growth factors.

Liebig's law is frequently illustrated by the staves of a barrel with the lowest stave representing the fertility element that is limiting yield. As the barrel suggests, there are many factors that can limit plant growth. But none are more important than nitrogen, phosphorus, and potash.

Fertilizer is, in the opinion of many experts, the most important single key to profitable hay yields. Yet it's still true today that while more farmers are fertilizing their forage crops for top profits, only one out of 7 or 8 acres of forage in the U.S. gets any fertilizer – and then at a relatively low rate per acre. Compare this to the nation's corn acreage of which well over 90% is fertilized.

With today's rapidly changing prices for production inputs, including fertilizer and farm products, it's hard to come up with specific figures on net returns from fertilization. And, of course, overall crop response depends on soil fertility levels at the time fertilizer is applied. That's why a regular soil testing program is so essential.

Soil Sampling

The grower's ultimate goal is to maximize crop yields while reducing input costs in order to maximize the land's profit potential. Through accurate soil sampling, growers can best estimate nutrient levels in the soil. That way, fertilizers and manures need only be applied where required and in the volumes necessary to provide the best nutrient balance for optimum plant growth. Soil sampling is not just a principle of good land stewardship, but it is also indispensable for reducing costs and maximizing yields.

As the barrel suggests, there are many factors that can limit plant growth. The most important are nitrogen, phosphorus and potash.

Soil composition, slope, and moisture can vary greatly among field locations on a single farm, and will most certainly vary across counties and states. Many states' extension offices provide specific local guidelines for soil sampling and can provide detailed information on soil types, slopes, and moisture levels. Working with local extension agencies, growers can get an understanding of local soils and conditions, allowing them to utilize technology and soil sampling to increase profits while being good stewards of the land.

Growers applying livestock and poultry manures should be especially conscious of nutrient loads present in the soil because nutrient levels will vary greatly by the type and quantity of manure applied. Today's most progressive producers are sampling not only the soil but the manure they are spreading. In this way they are able to best utilize available manure nutrients and provide supplement fertilizer applications to balance soil nutrient levels. Advances in spreader technology provide operators with direct feedback on the volumes of manure applied and represent the first steps in the manure management practices of tomorrow.

Economics of Fertilization

University of Maryland forage crops specialist Les Vough commented recently on the profitability of fertilization by simply saying, "Times have changed!" The price of potash in 2010 is almost triple what it was in the 1980's and 90's when many of our currently used fertilizer recommendations were developed. While the potash price went from $0.15 to nearly $0.40 per pound, the hay price remained relatively constant during the same period. So the economics of higher rates of fertilization are much different today than 30 years ago, and growers need to look closely at hay production costs vs. returns in their individual farm operations.

Vough explained that, as a rule, alfalfa removes about 60 lb K_2O per ton of hay harvested. In today's dollars that's $24 worth of potassium fertilizer in every ton harvested or $120 for every five tons of hay harvested per acre.

To see how this affects a grower's bottom line, it is necessary to establish a value for the potassium removed. On a twenty-five acre stand harvested at five tons yeild per acre, 7,500 pounds of potassium is removed from the soil with a value of nearly three thousand dollars. When you evaluate those twenty-five acres as part of a three-cut harvesting system and consider seasonal diminishing yields, the total annual value of removed potassium is in excess of $6,000 annually.

In most instances, however, soil fertility levels may not require the full application of sixty pounds of K_2O per ton of hay harvested. Thanks to the positive effects of a faithful crop rotation schedule, periodic manure applications, and residual effects of fertilization, most often a reduced application rate is sufficient to keep the soil nutrient levels balanced. However, only through a long term program of soil testing is it possible to accurately match application rates to maintain optimum soil fertility in line with a stand's yield potential.

Lastly, Vough commented that, based on today's economics, he recommends keeping soil fertility high in the initial years of a stand when yield potentials are the greatest . Then, as stands age in their fourth and fifth year, application rates of potash can be reduced to cut production cost while still achieving the best returns.

Forage Fertilization Dividends

Adequate fertilization based on soil testing can give your hay crops a big boost in many ways. Here are several. It (1) helps seedlings get off to a fast start, (2) assures consistently higher yields, (3) helps plants survive winter, (4) permits earlier, more frequent cutting for top quality, and (5) helps plants recover better from insect attacks.

One cannot overemphasize the need for a good soil fertility program related to quality forages. Wisconsin reserchers emphasize that fertilizer applications also may initiate a host of chemical and physiological changes in forage plants that can significantly affect the health and nutritional status of animals consuming the forage. But the key purpose for fertilizing hay crops is still to produce higher yields of quality hay resulting in most profitable feed production. That includes more pounds of total digestible nutrients (TDN) for boosting milk production or putting on extra pounds of beef.

FIGURE 5-1

Effect of Different Nitrogen Rates on Yield and Protien Content of Coastal Bermuda

Pounds/N/Acre	Yield in Tons	% Protien
	2.67	7.9
100	4.38	9.1
200	5.93	10.5
400	8.59	11.7

Source: Texas A&M

In Ohio and Pennsylvania studies, for example, proper fertilization doubled the yield of TDN per acre. In a Texas A&M trial, increasing N rates on Coastal Bermuda grass from 0 to 400 pounds per acre more than tripled yields and increased protein from 7.9% to 11.7% (see Figure 5-1).

N, P, K – How They Work in the Plant

Hay crops require the same 16 elements considered essential for the growth of all other crops. A brief knowledge of the role of just three of these elements in plant growth should help you understand why a sound fertility program is so important.

(1) *Nitrogen* is a major constituent of proteins, and the chlorophyll of green plants is a nitrogen compound. It is, therefore, essential for photosynthesis, growth, and reproduction. The bacteria in well-nodulated legumes normally manufacture enough nitrogen from the air to supply their own needs and some of the needs of any associated grass. Pure grass stands, however, need a healthy supply of applied nitrogen.

FIGURE 5-2

Plant Food Utilization by Selected Crops

Crop, Annual Yield Level	N(lbs)	P_2O_5 (lbs)	K_2O(lbs)	Mg(lbs)	S(lbs)
Alfalfa - 5 tons	250	75	250	20	20
- 8 tons	400	120	400	40	40
- 10 tons	500	150	500	53	51
Bermudagrass - 6 tons	300	84	252	27	27
- 10 tons	500	140	420	45	45
- 12 tons	600	168	504	54	54
Clover - grass - 3 tons	150	45	180	15	15
- 6 tons	300	90	360	30	30
- 7 tons	350	105	420	35	35
Corn - 200 bushel grain	200	80	60	18	15
- stover	125	30	200	47	18
Grain Sorghum - 8,000 pounds grain	120	60	30	14	22
- stover	130	30	170	30	16
Soybeans - 60 bushel grain	190	60	84	17	12
Tall fescue - 5 tons	250	75	250	20	–
Wheat - 80 bushel grain	80	70	25	12	5
- straw	42	20	135	12	15

Source: Adapted from: Penn State University Agronomy Guide

(2) *Phosphorus* is one of the nutrients generally deficient in many soils that do not receive manures and the one most universally applied to forage crops. In plants it is required in photosynthesis, transfer of energy within the plant, and the making and breakdown of carbohydrates. It's a key nutrient in growth and cell division and tends to be concentrated in young, actively growing tissue.

(3) *Potassium* does not become a part of any particular plant constituent but is vital to many plant functions – the formation of sugars and starch, the movement of these compounds within the plant, food storage for winter hardiness and fast recovery after cutting, protein synthesis, and many similar functions.

Forage Nutrient Needs

Now let's talk about specific nutrient needs. As stated previously, the bacteria in well-nodulated legumes almost always manufacture enough nitrogen (N) from the air to supply their own needs and at least some of the needs of any associated grass. Mainly grass stands, however, require a healthy supply of nitrogen balanced with phosphorus (P) and potassium (K).

Figure 5-2 shows the average plant food utilization by selected crops at various yield levels. This should explain why it takes lots of fertilizer to produce high yields. The average removal of P_2O_5 and K_2O is approximately 15 pounds and 60 pounds respectively per ton of alfalfa hay. Thus, an 8-ton per-acre crop of alfalfa actually removed about 480 pounds of K_2O.

But, remember, it's not enough just to replace what the crop removes. As explained by Penn State soil specialist Doug Beegle, no crop is 100% efficient; there must be more nutrients present in the soil and available to the plant than it actually needs. In fact, for most plants and in most soils, there should be twice as much nitrogen and potassium, and three times as much phosphorus available as is needed. When soil conditions are adverse, even more may be required.

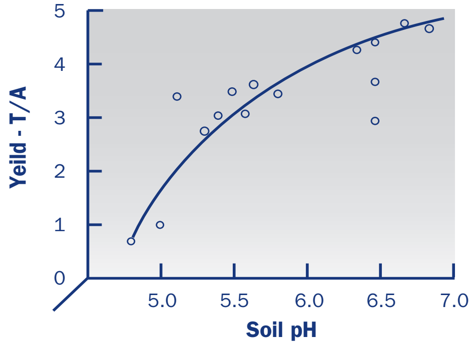
Start at Establishment

Remember, most hay species grow best when the soil pH is near 7.0. So be sure to lime those fields to be seeded well in advance of seeding. This was stressed in the chapter on Lime, but Figure 5-3 based on Cornell University studies, reemphasizes the importance of lime for one crop, alfalfa.

It's also well documented that adequate fertility is essential to the success of new seedings. In most studies, phosphorus applied at the time of seeding was the key element in the early establishment of both legumes and grasses. The use of some nitrogen and potassium, along with phosphorus, is also usually beneficial, depending on your existing fertility level. On the other hand, in many studies, potassium and nitrogen, either alone or in combination, were definitely detrimental to young seedlings when phosphorus was not included.

■FIGURE 5-3

Alfalfa Yield Declines Rapidly as pH Drops Below 6.5



Sources: Cornell University

And don't ignore the value of manure. Most dairy and livestock producers apply considerable amounts of manure in their rotation before alfalfa, thus assuring high nutrient levels at the time alfalfa was seeded.

Proper placement of fertilizer in relationship to seed (band seeding) is also important, especially on low fertility soils. In one experiment, for example, radioactive phosphorus was used to determine the time and amount of phosphorus absorption by alfalfa seedlings when phosphorus was placed 1.5 inches deep and at several distances from the seed. As shown in Figure 5-4, seedlings had to be directly over or within one inch to the side of a fertilizer band in order to obtain 60% or more of their phosphorus from applied fertilizer during the first 2 months of growth.

Other benefits of band seeding will be given in a later chapter.

■FIGURE 5-4

Phosphorus Uptake by Alfalfa Seedlings When Placed at Several Distances from the Seed

Distance Between Phosphorus & Seed	% of Phosphorus Seedlings Obtained from Fertilizer	
	Months After Seeding	
Inches	1 Month	2 Months
0	98	77
1	66	62
2	15	50
3	3	24
4	0	7

FIGURE 5-5

Response of Alfalfa to Lime and Fertilizer

Fertilizer and Lime Treatment	5-Year Average Yield
	Tons/Arce
0 - 0 - 0 and no lime	3.22
0 - 0 - 0 and lime	5.01
0 - 150 - 300 - 3, no lime	6.46
0 - 150 - 300 - 3. lime	7.16

Sources: Rutgers University

Fertilizing Legumes for Top Profit

For legumes, especially alfalfa, potash is the key to high yields, high-quality hay, and long-lived stands. But applying both potassium and phosphorus before planting, followed by yearly topdressings, along with adequate lime, is necessary to establish and maintain vigorous legume stands. New Jersey data also shows the value of a balanced fertility program on yield. As shown in Figure 5-5, over a 5-year period, lime alone increased average annual yields over the no-lime plots. But not until lime, P_2O_5, K_2O, and boron were properly applied were top yields obtained.

Legumes Respond to Potassium

Forages, especially legumes, have a big appetite for potassium.

Potassium accumulates in young stems and leaves where it's removed by cutting. In comparison, small grains and corn return considerable potassium to the soil through stalk residues when these plant residues are not harvested for bedding.

Minnesota and Wisconsin researchers, in separate studies using different levels of K_2O, demonstrated what potassium can mean to legume yields. Rates of K_2O up to 240 pounds per acre were needed before potash moved

FIGURE 5-6

Total Alfalfa Yield Responses Resulting from P and K Fertilization over a 3-Year Period

Annual P_2O_5 Rates	Annual K_2O Rates 0	72	144	288
	3-Year Yield - Tons/A*			
0	–	2.83	3.06	2.53
35	2.66	3.80	4.10	5.02
69	3.38	4.67	4.76	6.46
138	3.57	5.32	6.23	7.03

*Total 3-year yield of unfertilized plots was 8.19 tons

Souece: Based on Iowa State University studies down 3 inches. Topdressing didn't boost potassium levels in plants until late in the second year after application, researchers report.

Don't be too disappointed if potash doesn't go to work right away. It might be the application is setting the stage for improved yields a year later. That's one reason annual topdressing is recommended rather than waiting until yields appear to slack off.

Phosphorus for Legumes

It pays to remember three facts when fertilizing legumes with phosphorus. (1) Applied P moves very little through the soil profile, (2) phosphorus becomes fixed and relatively unavailable in some soils – especially in the finer-textured, more acid soils, and (3) recovery of applied P ranges from 10%-30%.

To avoid P shortages, the crop needs plenty of P available at all times throughout the rooting zone. Legumes actually need about a third as much phosphorus as potassium. However, since phosphorus does move slowly in the soil, it may take a while before yields perk up. That's why it's important to plow under a part of the application when establishing seedings. And in some cases it may be feasible to meet all of the phosphorus needs with a big plow-down application. However, topdressing phosphorus based on soil tests is usually a must for maintaining those high yields. The importance of P application for maintaining both yield and soil test levels are shown in Figure 5-7 published by Kansas State researchers.

When to Topdress Legumes with P_2O_5 and K_2O

Generally, when you apply potash to legumes is not critical – if adequate amounts are supplied for the growth period. For single applications, apply in the late summer, soon after mid-August harvests. Good weather, a less busy season for the grower, and a good time for the fertilizer industry to apply the material are some of the reasons. But where higher rates of potash are needed to produce and maintain satisfactory alfalfa yields, split applications, one half in the fall and one half after first cutting, may be advisable.

For phosphate, a combination of pre-plant incorporation plus small

FIGURE 5-7

Effect of P on yield and soil test levels

P_2O_5 Rate	3-Year Average Yield	Intial	P Soil Test Level 2nd Year	3rd Year
lb/A	T/A		-------- lb/A --------	
0	7.5	19 (L)	10	8
40	8.9	19	15	11
80	9.4	19	18	17
120	9.8	19	29	27

Sources: Kansas State University

annual topdressings appears best for legumes. When you topdress phosphate during the year doesn't seem to make much difference.

What is important, however, is the ratio of phosphate to potash in your topdressing fertilizer. After studying the results of many trials throughout the U.S., agronomists for the Potash and Phosphate Institute feel that "a fertilizer ratio of 0-1-4 (N, P_2O_5, K_2O) may be needed for intensive, high-yielding legume production on many soil types." Based on Maryland studies, for alfalfa at least, annual applications of 100 pounds P_2O_5 per acre and 400 pounds K_2O per acre may be about right for yield goals of 6 to 8 tons of hay per acre.

Micro Nutrients Are Important, Too

While phosphorus and potassium levels most often need to be corrected, especially for legumes, secondary elements and micronutrients in some areas are also shaving legume yields. The secondary elements are calcium, magnesium and sulfur. The micronutrients are boron, chlorine, copper, iron, manganese, molybdenum, and zinc. Of these elements, calcium and magnesium are generally supplied through a good liming program. Sulfur, boron, and molybdenum usually cause the most problems. Here's a brief rundown on how these three affect alfalfa:

Sulfur: Many trials report alfalfa responding to S fertilization. And as stated by Minnesota researchers, "Sulfur may be one of the weakest links in alfalfa management." Sulfur is linked to alfalfa quality through its close relationship with nitrogen and protein development. And, there are at least three factors at work to make sulfur deficiencies a big problem in some areas. First, increased use of nitrogen, phosphorus, potassium, and lime put more stress on soil supplies of sulfur, and secondary elements and micronutrients. Second, the soil gets less sulfur from "smoke fallout." Years ago, with heavy coal use in factories, soils received large amounts of sulfur precipitation, as much as 200 pounds per acre per year close to industrial centers. Now, with coal use down and pollution control devices on all coal burning plants, sulfur precipitation is down.

Third, fertilizer today contains less sulfur. The 0-20-0 superphosphate common years ago contained 11.5% sulfur, compared with less than 1% in the concentrated form today (0-46-0).

Sulfur can be applied effectively with your annual P-K fertilizer program. And as shown in Figure 5-8, consistent high yield production may require as much as 50 to 100 pounds per acre of S applied annually on some soils.

Boron: Alfalfa has a relatively high boron content of 0.04% – eight times as high as corn's 0.005%. That's why alfalfa is more likely to run into problems than other crops. Boron deficiencies may cut yields 20% before the problem is noticed.

An annual topdress fertilizer with boron increased alfalfa yields .5 ton per acre in some cases in Maryland trials.

It is recommended to broadcast a mixed fertilizer containing boron. Drilling boron fertilizer with the seed, however, may cause seed injury.

Although boron deficiency shows up most often in drought periods, it may also occur on easily leached, sandy soil. Look for top leaves yellowing, with the whole plant turning yellow as severity of the deficiency increases. (Sometimes leaves turn red or brown instead of yellow.) Flowers may also die, turn brown and fail to produce seed. Plants may be stunted with shorter internodes. But don't confuse boron deficiency with leafhopper damage, entomologists warn. Both produce similar symptoms and often show up at the same time of year.

Molybdenum: Deficiencies appear most often in acid, sandy soils. However, a few molybdenum deficiencies have been reported on limed or naturally neutral soils. Molybdenum is an essential nutrient for bacteria which form nitrogen-manufacturing root nodules. On acid Wisconsin soils, for example, molybdenum-short legumes showed no nodules, even though seed had been carefully inoculated.

At this time other micronutrients are not considered a major problem in the production of legume hay.

Apply Micronutrients Carefully

One word of caution, high micronutrient levels may be toxic to both plants and animals. Don't apply unless local recommendations call for these elements, or a special test on your soil shows they are needed.

Nitrogen Key to Higher Grass Yields

So far we have devoted all of our attention to legumes. But grasses need lots of fertilizer, too, for top yields. Although grasses need all three major nutrients, nitrogen, phosphorus, and potassium, nitrogen is the real key to higher yields. In South Dakota trials, for example, applying 160 pounds of nitrogen per acre on native grasses increased yields 136% over unfertilized fields. In Texas trials, researchers almost tripled

FIGURE 5-8

Yield, percent S, and the S removed in intensively managed alfalfa.

S Rate lb/A	Yield T/A	S %	S Removed lb/A
0	3.3	0.16	11
36	6.7	0.25	38
72	7.7	0.33	49

Sources: California Data

Bermuda grass yields with yearly applications of 190 pounds nitrogen and 30 pounds phosphorus.

Bigger yields from nitrogen fertilizer, however, are only one bonus. Generally, higher nitrogen content means higher feeding value because of extra protein. Nitrogen fertilizer greatly improves forage quality as measured by crude protein. In Nebraska tests, boosting nitrogen rates on bromegrass from 0 to 160 pounds an acre increased crude protein content from 9.0% to 14.8% (Figure 5-9).

Timing N Applications on Grasses

There's no hard and fast rule to follow for applying nitrogen. Timing depends mainly on grasses grown, length of growing season, and rainfall.

Nitrogen timing on cool-season grasses isn't critical if a split application is made. Cool-season grasses make the most growth in early spring and fall, so applying half the nitrogen in either season helps speed nutrient uptake. A second application, after the first cutting, lets you boost fertilizer rates if moisture conditions are good, or you can cut back in a dry year.

Waiting to fertilize warm-season grasses until mid-May or just before they break dormancy helps control weeds. If fertilizer is put on in early spring or late fall while grasses are dormant, it actually feeds the weeds, allowing them to take over stands.

For cool season tall grasses, such as bromegrass and orchard grass grown for hay, a split application of nitrogen is best. Make the first application (60 pounds N) in early spring, another 40 or so pounds after the first cutting. Higher rates may pay off in some cases, but could result in serious lodging and harvesting problems.

Conversion to nitrate nitrogen, however, slows greatly at 50° F. and stops completely at 32° F. Ammonia nitrogen and urea, which change to ammonium in the soil, are tightly held against leaching by clay particles and soil organic matter.

But too much nitrogen on certain cool season grasses, regardless of when you apply it, can result in increased winter damage unless other good management practices are used. Briefly, the more nitrogen you apply to grasses such as Kentucky bluegrass, tall fescue, orchard grass, and timothy, the more frequently you must harvest; up to five or more times under some conditions, in order

FIGURE 5-9

Effect of Nitrogen on Crude Protein Content of Bromegrass

Nitrogen pounds per acre	Precent crude protein in forage
0	9.0
40	10.2
80	11.9
120	13.0
160	14.8
200	14.8

Source: University of Nebraska

to hold stands. The same is true for bromegrass and reed canary grass, but these two species cannot be harvested quite so frequently.

Balancing N with Phosphate and Potash on Grasses

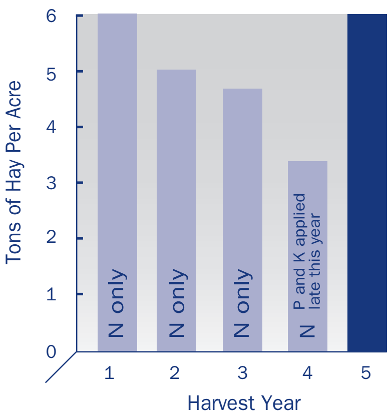
Although nitrogen alone may do wonders for grass growth, the right balance of nutrients, especially potash, is a must for good stands and production.

In Cornell studies, yields of orchard grass getting 300 pounds nitrogen yearly dropped until 100 pounds of P_2O_5 and 200 pounds K_2O were added late in the fourth harvest year (Figure 5-10).

After researchers balanced the three major nutrients, per acre hay yields jumped more than 2 tons between the fourth and fifth harvest year.

FIGURE 5-10

Effect of Balancing Nutrients on Orchardgrass Yield



Sources: Cornell University

Potassium Affects Protein Level

To get the most from nitrogen applications, potassium levels must be optimum. Grasses can't change nitrogen to protein without adequate potassium. In some cases adding potassium to severely deficient soils may increase protein content in plants by 50% or more.

Also, applying high rates of nitrogen without adding potassium can cause animal health problems. Non-protein-nitrogen compounds (NPN) often build up in plants if soils are high in nitrogen and low in potassium. Other researchers believe high NPN levels may cause ammonia intoxication or other problems such as tetany, milk fever or ketosis.

Pre-plant potassium applications help establish seedings, and annual top-dressing keeps stands healthy. Missouri agronomists point out that high yielding forage such as orchard grass remove more potassium than an 80-bushel corn crop. Soil potassium levels decrease rapidly without annual applications.

Don't Overlook Phosphorus

For years, phosphorus has been credited as being important in establishing seedings. However, it's just as important for maintaining high yields.

While phosphorus used by grasses and legumes is only about a third that of potassium, it's important to top-dress phosphorus according to soil test recommendations. Many hay fields may require as much phosphorus as potassium, authorities agree.

Since phosphorus moves only a short distance in the soil, plowing down phosphorus before seeding helps get it into the root zone. But don't plow down too deeply.

Plowing phosphorus 10 to 12 inches deep may put it out of reach of young seedlings, especially in deficient soils. If soil phosphorus level is low, your best bet may be to plow under part of the application, and work more phosphorus into the top 2 or 3 inches. This gives seedlings a "starter feed," and a deeper reserve for later growth.

Nitrogen for Mixtures

Whether or not to apply nitrogen to legume-grass mixtures depends on the percentage of legumes in the stand and stage of growth. Soil bacteria form nodules on legume roots. Well-nodulated legumes draw enough nitrogen from the air to supply forage needs, if mixtures have about 40% or more legumes.

Until nodules form, however, seedlings depend on soil nitrogen for growth. On deficient soils, a nitrogen-carrying fertilizer will supply enough nitrogen until root nodules take over. Late fall seedlings also benefit from a nitrogen-carrying fertilizer if soil temperature is low.

Some authorities feel that with 5- to 6-ton yields, legumes may not supply enough nitrogen for grasses in a mixture. If you do spread nitrogen on a grass-legume mixture, be sure plants have plenty of potassium available. Otherwise, grasses stimulated by nitrogen may crowd out legumes by robbing them of other nutrients, especially potassium.

In fact, the results of many studies throughout the U.S. emphasize that, because of severe competition for K by grasses grown with most cool season legumes, it may be necessary to maintain even higher levels of available soil K for mixtures than for pure stands.

This is clearly shown in Figure 5-11 summarizing studies in Virginia. Note that in this alfalfa-grass mixture, when potash was applied liberally, alfalfa had only 8% less K than the grass. As the application of potash was reduced, the alfalfa absorbed much less K than the grass.

Grain crops are also better at taking up potassium. For this reason, it's also important to use enough fertilizer when establishing legumes with a nurse crop.

If nitrogen is applied to mixtures, Purdue agronomists recommend using no more than 40 pounds actual nitrogen per acre. Best time to apply is after the first cutting, they feel.

Using Animal Manures

The use of properly handled and stored animal manure can also affect your forage fertilizer needs. Manure contains the three major plant nutrients – nitrogen, phosphorus, and potassium, as well as essential elements like calcium, sulfur, boron, magnesium, manganese, copper, and zinc.

"However," reminds Penn State's Doug Beegle, "Although manure does contain many plant nutrients, it's most valuable for its nitrogen content, and it is best used for those crops that require large nitrogen applications and where the manure can be incorporated into the soil."

Normally, manure applications to established legume stands are not recommended. Applying manure to alfalfa, for example, encourages competition from weeds and grasses and may also introduce weed seeds. In addition, the nitrogen applied to the legume stand tends to reduce the fixation of atmospheric nitrogen by the legume. However, summer applications may be effectively made to old legume-grass mixtures or to pure grass stands.

When used, manure should be applied to fields at the rate which supplies just the amount of nutrients that the crop will use.

If you are fortunate enough to have access to a manure analysis service in your area, give it a try. A manure analysis, along with a good soil testing program, may save you fertilizer dollars and also help to keep your soil nutrient levels where they should be.

FIGURE 5-11

Potassium Content of Alfalfa & Orchard grass When the Two Were Grown in a Mixture

Rate K_2O lbs/A	% K Dry Weight Grass	% K Dry Weight Legume	K Content in Legume Relative to Grass
0	2.71	0.70	26
50	3.46	1.21	35
100	4.01	1.76	42
400	3.85	3.53	92

Source: Virginia Polytechnic Institute

Quality Seed, Proven Varieties, and Mixtures

A very important piece in your profitable forage program is high-quality seed of adapted species, varieties, and mixtures. Quality seed is especially important with small-seeded perennial crops such as alfalfa and grasses. Seeds of these species are extremely small and contain very little stored food material. Start with good seed and then follow with good seeding practices to insure success.

Forage specialists agree that another very important piece in your profitable forage program is high-quality seed of adapted species, varieties, and mixtures. Quality seed is especially important with small-seeded perennial crops such as alfalfa and grasses. Seeds of these species are extremely small and contain very little stored food material. Thus, unless you start with good seed and then follow with good seeding practices, you can end up with a seeding failure.

Quality – What Is It?

Quality in seed can be related to the *genetic quality, germination,* and *purity* of a given seed lot or the vitality of the individual seed. These are big words, but they have lots of meaning.

A seed with good vitality is one that not only germinates but also produces a seedling capable of developing into a mature plant. Many factors affect vitality, including vigor of parent plants, climatic conditions while the seed is maturing, seed maturity at harvest, seed storage conditions, and age of seed.

Another factor often associated with seed quality in legumes is the percentage of hard seeds. Hard seeds are viable seeds that do not take up water when exposed to moisture, and remain dormant in the soil for varying periods after seeding. This impermeability of the seed coat to water or oxygen is of special concern in many seed lots of alfalfa, bird's-foot trefoil, and crown vetch.

In the past, as much as 15% to 25% hard seed in legumes was thought to be advantageous in the event of poor or unfavorable weather conditions following planting. But this concept has been abandoned on the basis of studies that show hard seed to have little value in commercial agriculture. Late germinating alfalfa seeds, for example, cannot compete with established seedlings and plants and do not make a significant contribution to improving stands.

Certified Seed Assures Quality

Buying certified seed is usually a good way to be sure you're getting the quality seed you pay for.

Seed certification is the system used to maintain the *genetic identity* and *purity* of varieties during seed production, processing, and distribution. It assures adequate standards of seed quality in other ways, too. Thus, certified seed is of known heredity, identified as to variety, and traceable through records to a specific lot of breeder seed. Varietal purity can be insured only if forage producers plant certified seed.

The Plant Variety Protection Act (PVPA) offers further protection for named varieties of sexually reproduced plants such as alfalfa for which a certificate has been duly issued pursuant to the Act. The Federal Seed Act makes it unlawful to sell non-certified seeds of a variety certified under the PVPA. Certification assures you are getting what you pay for, and it also insures freedom from weeds and other crops.

Figuring Seed Worth

At any price, seed is a very small part of the total cost of growing a crop. You can look at seed price versus cost in another way when you're choosing varieties for your farm. Seed quality in terms of germination, purity, etc., is very important. But so is the genetic quality of that variety for your particular area, i.e. how well will that variety perform for you over the entire stand life. That's where improved varieties with good tolerance or resistance to the major pests that attack the crop really shine.

Research has proven, for example, that over time, a variety with good overall pest tolerance or resistance for a given area will outperform the variety with high resistance to one pest, but with low or no resistance to others. Plant breeders call this multiple pest resistance.

And you, the producer, should make your decision on a variety based on its long-term returns, not on a short-term price of seed. Another more critical way to compare varieties is to make a computer "head to head" analysis. In Figure 6-1, two alfalfa varieties of similar winter hardiness and adaptability were compared in a "head to head" analysis in 69 tests across the country. The table compares the pest

FIGURE 6-1

Comparison of Two Winter-hardy Alfalfa Varieties in Terms of Pest Tolerance, Yieild and Cash Hay Value

Variety:	Y	Z
Bacterial wilt	HR	R
Fusarium wilt	HR	MR
Verticillium wilt	HR	LR
Phytophthora root rot	HR	LR
Aphanomyces root rot	HR	MR
Anthracnose	HR	LR
Pea aphid	R	LR
Spotted alfalfa aphid	R	R
Blue alfalfa aphid	MR	LR
Leafhopper	HR	S
Stem nematode	MR	MR

Key:
HR = High Resistance
R = Resistant
MR = Moderate Resistance
LR = Low Resistance
S = Susceptible

Sources: Data Courtesy WL Res, Inc.

Yield Analysis (Tons/Acre)

	Variety		
Year	**Y**	**Z**	**Advantage**
Yr. 1	6.21	5.88	330 lbs.
Yr. 2	6.80	5.93	870 lbs.
Yr. 3	6.65	5.71	940 lbs.
Yr. 4	6.48	4.88	1,600 lbs.
Total	26.14	22.40	
4 Yr. Avg.	6.54	5.60	
Avg. per Yr. 647 lbs./acre			

Value Analysis ($ Per Acre)

Stand Life 4 yrs. Seeding Rate 15lbs/acre Seed Cost ($/Lb), Y $2.25, Z 1.75	Variety	
	Y	**Z**
Avg. Yield/Acre	6.54	5.60
Hay Price	$120	$120
Gross/Acre/Year	$784.80	$672.00
Seed Cost/Acre	$70	$40
Adj. Gross/Acre/Year	**$714.80**	**$632.00**

resistance of the two varieties as well as a yield analysis and value analysis using recent hay marketing information. In this comparison, you can see the benefit for the superior, multiple pest resistant variety especially as the stands got older.

Thus, the bottom line is: what the return on investment will be for a given variety and not what it costs per pound. Cheap seed may indeed turn out to be more costly in the long run.

Lab Germination vs. Reid Stand

Tests for germination, purity, and other factors don't always tell the whole story. And that's where seed vitality comes in.

Field conditions are never as favorable as laboratory conditions and unfavorable field conditions hit germination and field stands harder on low-quality seed.

You can check out the effect of the above theory this way. A given lot of red clover seed with a lab germination of 90% may show 50% field germination. But seed with 70% lab germination may show only 30% field germination. With these figures and the formula in Figure 6-2, you can figure the seed cost which actually contributes to field stand.

Substitute alfalfa seed prices of $175 and $225 per hundredweight and you'll come up with a difference of nearly $200! Look at it this way and you're soon convinced that quality seed pays!

For some seeds the risk of poor stands due to unfavorable field conditions can be offset, in part, by seed treatments with approved fungicides. Your local seed authorities can guide you on the approved fungicides that are best for your area.

Read and Save that Seed Tag

Most states have laws that require labeling of all seed sold or intended for sale. This label, or tag, describes the seed and helps you determine the seed value. So be sure to study it thoroughly.

Generally, it's best to choose seed varieties adapted to local conditions, including resistance or tolerance against diseases and insects in your area.

Understanding seed tag terminology can save you money and disappointment. Use these points as a guide, since seed labeling laws vary from state to state. Here's what to look for:

(1) *Kind of Seed* is always listed, but the variety may or may not be.

(2) *Lot Number* shows a definite amount of seed of uniform quality and represented by a given seed test.

(3) *Percent of Purity* is stated as to the kind of crop and variety. If the variety is unknown, the lab analysis report will say, "test not based on variety," and the percentage of pure seed will be based on the crop only. A certified seed tag gives added assurance of varietal purity.

(4) *Other Crop Seed* gives content of other kinds of crop seed in the bag.

(5) *Weed Seed* shows total percent of all weed seed present.

(6) *Inert* indicates percent of chaff, dirt, cracked seed and so on.

(7) Noxious Weeds must be shown by name and number per pound. Seed containing prohibited noxious weed seed can't be sold.

(8) *Germination* gives percent of seed producing normal sprouts during the standard lab germination test not including seeds with a hard seed coat.

FIGURE 6-2

Red Clover Seed- **Price per 100 lb ÷ (Purity x Field Germination) = Cost / 100 lbs contributing to field stand**

Bargain Seed: $50 ÷ (0.90 x 0.30) = $185 per 100 pounds contributing to field stand.

Quality Seed: $60 ÷ (0.99 x 0.50) = $121 per 100 pounds contributing to field stand.

However, hard seeds are live seed and will germinate later.

(9) *Germination Plus Hard Seeds* indicates the total germination.

(10) The seed tag may also include *date of test, origin and the name and address of the party labeling the seed.* Any chemically treated seed carries a separate tag indicating treatments used and precautions necessary.

It's also a good idea to save those seed tags until after the crop is harvested, authorities suggest. These tags are your record of seed quality. Too often they're thrown away at the time of seeding and then you're out of luck if they are needed for evidence later on.

About Species and Varieties

Plant and soil characteristics are major considerations when selecting forages for your farm. Depending on where you live, plant factors you must consider include: general growth habit, speed of recovery, winter-hardiness, disease resistance, insect tolerance, drought tolerance, and temperature tolerance.

Whether you plant pure legume stands or mixed alfalfa-grass stands, selecting good seed builds a money-making forage program. The payoff comes when the baler rolls through the field.

Depth of soil, soil texture and structure, erosion hazard, and internal drainage are among the soil factors that may limit the species and varieties adapted for your area.

The Extension Service in your state or province publishes up-to-date findings on recommended species and varieties for your conditions. Be sure to check with local agricultural authorities for the latest hay variety recommendations for your area.

Consider Compatible Mixtures

Pure stands of alfalfa, other legumes, or grasses may be the best bet for your conditions. But if you have a choice, check out the possibilities of simple legume-grass mixtures as well.

Why mixtures? Researchers have shown that in many areas, over a period of years, simple mixtures of legumes and grasses that grow well together are frequently higher yielding and more persistent, especially on soils with variable drainage. Mixtures are also easier to harvest and cure as hay.

Including the grass will generally result in a feed only slightly lower in protein, and there is almost no difference in feed value as indicated by TDN. Furthermore, feeding legume-grass mixtures instead of pure legumes to ruminant animals helps to minimize bloat. Milk fever and reproduction problems may also be reduced when mixtures, rather than pure legumes, are fed to dairy cows.

Here are several tried and proven hay mixtures, along with seeding rates, of several cool season legumes and grasses for various soil conditions found across the northeastern and north central states. All seeding rates are given as pounds per acre:

Well-drained soils (long term hay) Alfalfa 8-12 pounds with one of the following: orchard grass 3 pounds; smooth bromegrass 8 pounds; timothy 4 pounds; perennial rye-grass 6-8 pounds; reed canary grass 8 pounds.

Poorly to well-drained soils (long term hay or pasture) Bird's-foot trefoil 6-8 pounds with one of the following: timothy 4 pounds; bromegrass 5 pounds; reed canary grass 6 pounds.

Poorly to well-drained soils (short term hay) Red clover 6-8 pounds and timothy 4-6 pounds.

For other compatible hay mixtures suitable for your area, check with your local agricultural authorities.

CHAPTER 7

Get Stands Off to a Good Start

It's no secret that if you want top forage yields you must start with good stands.

If asked why your seeding failed, you may say, "poor quality seed," "dry soil," or perhaps "too many weeds." All of which point to the fact that successful seedling establishment of small seeded hay crops is governed by many factors – quality seed, proper seedbed, adequate lime and fertilizer, seeding at the right time, the best crop sequence, good seeding techniques, and satisfactory control of troublesome weeds and insects.

Successful seedling establishment of small seeded hay crops is governed by many factors – quality seed, proper seedbed, adequate lime and fertilizer, seeding at the right time, the best crop sequence, good seeding techniques, and satisfactory control of troublesome weeds and insects.

Moisture, Temperature, and Light

Other factors are important, too. Forage seeds require moisture, oxygen and some warmth to germinate and grow. The seeds are small and must be planted close to the soil surface. One-quarter to three-eighths-inch planting depths are optimum under most conditions.

Too much or too little water may harm the seeds and seedlings. In wet soils, oxygen may be lacking while temperatures may be too cool for germination and seedling growth. Then, too, some seeds can absorb water and start to germinate in soils too dry for survival of small seedlings.

Light, both intensity and day length, has a big influence on the early development of forage plants. Reduced light intensities, due either to excessive cloudiness or competition from crops or weeds, may be responsible for many seeding failures of both legumes and grasses.

Greenhouse studies at Penn State University show how important light is. Under controlled conditions, top growth of bird's-foot trefoil was reduced about 90% by reduced light intensities due to shading. Root growth was affected more severely than top growth.

Plants growing together may shade one another to almost the same degree. Under the dense stand of an oats crop, for example, light levels may be reduced by 95% or more. Such levels may be too low for the seedling to survive.

Some forage seedlings are more shade tolerant than others. But three words, "legumes like light," pretty well tell the story, regardless of species or variety.

We talk a lot about competition, but other factors may be working, too, one of which is called allelopathy. Allelopathy is any direct or indirect harmful effect by one plant or another through the production of chemical compounds that escape into the environment. A very important point concerning allelopathy or autotoxicity is that its effect depends on a chemical being added to the environment, thus separating it from the competition effects noted earlier.

While not all researchers agree, there is plenty of evidence to suggest that alfalfa yields and stand densities are greater when alfalfa is rotated with soybeans, corn, or grasses, compared to growing alfalfa after alfalfa. This is supported by the research shown in Figure 7-1.

The University of Illinois concludes that there is a problem when alfalfa is seeded directly back into an old alfalfa stand, especially if the old stand is around 50% or more alfalfa.

How Many Plants per Acre?

Plant populations and hay yields usually decline as stands get older, especially with legumes. So what makes a productive forage stand? That may depend on where you farm, the crop you grow, and the age of stand. For example, in South Dakota, specialists consider 300,000 legume plants per acre (7 plants per square foot) as nearly ideal under most conditions in that area. A field with 300,000 plants per acre would produce as much hay in a drought year as a field with 150,000 plants, they report, but would yield more in a favorable season.

In North Dakota studies, alfalfa hay yields in the establishment year increased with increasing plant density, up to a point, but by the second production year, yields began to level out. Workers in that state concluded that under their growing conditions, near maximum

FIGURE 7-1

The Effects of Various Crop Sequences on Alfalfa Yields and Stand Count after 6 Years (Illinois data)

Cropping Sequence	Tons DM/Acre	Square Foot
Corn - alfalfa	3.8	4.6
Corn - soybeans - alfalfa	3.5	3.8
Alfalfa	1.9	2.0

Sources: University of Illinois

alfalfa yields can be produced with seeding rates that establish ten evenly distributed plants per square foot by the fall of the seeding year. Most researchers suggest a decline in alfalfa stand density has little direct effect on forage quality.

Minnesota authorities point out that just one pound of alfalfa seed per acre equals five seeds per square foot. Sow eight pounds of alfalfa and six pounds of bromegrass and you have 58 plants per square foot – if every seed germinated.

Everything considered, a good rule of thumb rule for legumes is about 500,000 strong seedlings per acre, or twelve plants per square foot. Somewhat more grass seedlings per square foot, especially for bunch grasses, may be desirable.

But you'll generally need to sow more seeds per acre to assure a good stand. It's not unusual for legume populations to drop to only five to ten plants per square foot within a short time after seeding. And, as plants reach full size, natural competition thins them out even more.

Thus, don't skimp on seed. But don't be extravagant either. Check on seeding rate recommendations with local authorities and be sure you're planting the right amount of seed to end up with high producing stands.

Remember, too, that seeding rate is related to seeding method. With precision seeding techniques and no-till seedings, for example, rates can safely be reduced by 15%-20% compared to broadcasting.

FIGURE 7-2

The Approximate Seeds Per Pound of Several Forage Crop Species Together with the Theoretical Number of Seeds Per Square Foot at Various Rates

Crop	Approximate Seeds/Pound	Seeds/Square Foot at Seeding rate per acre of 1 lb.	2 lb.	5 lb.	10 lb.
Alfalfa	221,000	5	10	26	51
Bluegrass, Kentucky	2,000,000	46	92	230	460
Brome, Smooth	137,000	3	6	16	31
Clover, Ladino	754,000	17	35	87	173
Clover, Red	293,000	7	13	34	67
Crown vetch	120,000	3	6	14	27
Fescue, Tall	246,000	6	11	28	56
Orchard grass	468,000	11	21	54	107
Redtop	5,605,000	129	257	644	1287
Reed Canary grass	660,000	15	30	61	152
Ryegrass	280,000	6	13	32	64
Sudangrass	55,000	1	3	7	13
Timothy	1,260,000	29	58	145	289
Trefoil, Bird's-foot	414,000	10	19	48	95

But, regardless of your intended seed rate or seeding technique, remember to calibrate your seeder before going into the field. Intended seeding rates and/or seeding depths are often quite different from what is actually done because the equipment is not properly adjusted or calibrated.

When to Seed

In some areas, it's possible to make a successful seeding almost any month of the growing season.

In general, seedings made prior to prolonged cool and moist weather are more successful than those made when it's hot and dry.

During the winter and early spring months, soil moisture has built up and spring moisture is generally good. Evaporation is less during the spring and soil moisture is retained longer during the establishment period.

To take advantage of the "ideal" conditions at this season of the year, including better moisture and less competition from weeds, spring seedings of most species should be made as early as a proper seedbed can be prepared. Seed alfalfa in early April without a companion crop and harvest your first hay crop in about 70 days. Exceptions to this "early as possible" rule are bird's-foot trefoil and crown vetch, which should not be seeded until soil temperatures reach the upper 50's.

Seeding in the late summer is also popular in some areas, and is considered especially ideal for many cool-season grasses because of cool nights, adequate rainfall, and warm soil. In general, grasses sown in the late summer or early fall root more deeply because the slower top growth is conducive to better root formation. However, some grass species, such as orchard grass, are relatively nonhardy in the seedling stage, while others, such as bromegrass and reed canary grass lack seedling vigor. Thus, these species must be seeded relatively early in the season to assure good winter survival. Success is most often achieved where at least 8 to 10 weeks of good growing weather precede winter dormancy.

FIGURE 7-3

The Percent Seedling Emergence of Several Forage Crops When Seeded at 4 Depths.

	Seedling Depth in inches			
Crop	**1/2**	**1**	**1 1/2**	**2**
Alfalfa	64	53	45	19
Clover, Alsike	53	49	9	4
Clover, Ladino	47	28	2	0
Clover, Red	56	62	22	14
Bluegrass, Kentucky	43	27	4	0
Bromegrass	78	69	51	24
Timothy	89	81	39	12
Redtop	64	33	2	0

Depth of Seeding

Hay legume and grass seeds are small and can easily be placed too deeply. The optimum depth for small forage seeds is one-quarter to three-eighths inch on heavy soils and one-half to three-quarters inch on light soils. These facts have been confirmed by research throughout the U.S. One look at Figure 7-3 will tell you how seedlings of several crops emerged when planted at different depths.

The Ideal Seedbed

Firm, fine, and mellow on the surface is one way to describe the ideal forage seedbed.

If the seedbed is not firm, tiny legume and grass roots will grow into air pockets between soil particles and die. That firm, fine, and mellow seedbed is also essential to permit uniform, shallow coverage of seed.

For the prepared seedbed, early plowing, followed by an occasional disking or harrowing, will aid in firming the soil in the seeding zone. Cultipacking before seeding is additional assurance of a firm seedbed.

A fine, firm seedbed improves chances of a successful forage stand. If the seedbed is too loose, tender legume and grass roots dry out and may die.

But whatever plan you follow, a seedbed firm enough for a man to walk across without sinking more than a quarter inch into the soil is a good rule to follow.

Inoculate Legumes

Rutgers University scientists pointed out many years ago that every acre is "covered" with 35,000 tons of free nitrogen in the atmosphere. Out of this vast nitrogen supply, only a tiny portion is taken by legumes. However, this nitrogen can be an important factor in cutting the amount of commercial nitrogen needed for the following crop. But legumes salvage nitrogen only if efficient legume bacteria (rhizobia) are present. And as pointed out by the late Dr. O. N. Allen, rhizobiologist at the University of Wisconsin, "Only 25% of all rhizobia found naturally in the soil are highly beneficial."

Legumes and bacteria establish a working relationship called symbiosis. The plant furnishes sugar, energy, and nodules formed by bacteria. The bacteria use energy to change free nitrogen from the air into a form used by the plants. Not all soils contain nitrogen-fixing bacteria of either the right kind for a specific crop or in sufficient quantity. Rhizobia content of soils varies according to geographical area, cropping history, and the soil itself. That's why it's important to inoculate legume seeds and with the proper strain of bacteria.

When and Why of Inoculation

Under favorable conditions and a continuous legume cropping history, the right kind and adequate amount of bacteria may be present in the soil horizon. However, in cases of low pH or low fertility, drought, high soil temperature, or persistent rains, the number of bacteria may be greatly diminished. Under such conditions, and especially when planting legumes for the first time on new land, or if four or five years have elapsed since the previous legume crop, seed definitely should be inoculated. A good rule of thumb is "when in doubt, inoculate."

Inoculation adds a fresh culture of effective rhizobia strains to seed and soil. Thus, rhizobia can begin working as the seed germinates and the plant starts growing. Since protein content in legumes is directly related to nitrogen content, effective inoculation is a major key to improving yield and quality.

Benefits of Inoculation

Research shows the more effective strains of legume bacteria can increase yield or protein content of legumes as much as 20%, on the average, over natural legume bacteria in the soil.

Without legume bacteria in the soil, legumes can't take nitrogen from the air. So inoculation is essential to give legumes the chance they need to reach full potential.

The amount of nitrogen legumes can fix varies widely, depending on many factors. Of these factors, the five most important are: (1) type of legume, (2) how well seeds are inoculated and effectiveness of inoculating bacteria, (3) soil type and fertility level, (4) soil pH, and (5) climatic conditions.

When conditions are favorable, a stand of alfalfa may fix nearly 200 pounds of nitrogen per acre. On the other hand, annual legumes such as soybeans will fix about 40 to 60 pounds.

Pre-inoculation

Seed can be hand inoculated with a fresh culture of the proper strain of bacteria just prior to sowing. However, much of the alfalfa and clover seed currently marketed is already pre-inoculated with the proper strain. Newer pre-inoculated techniques, such as the clay-based Dormal process, have proven highly effective and have extended the shelf life over conventional humus-based pre-inoculants. Nevertheless, pre-inoculated seed carried over from spring for summer or fall seedlings should normally be reinoculated prior to seeding.

Seed Treatments

Other newer seed treatments are also available to help get new seedings off to a good start. Studies in several states have shown that treating seed of several species with the systemic fungicide metalaxyl, marketed under the trade name *Apron*, provides good protection against present strains of the pythium and phytophthora seed and root-rot organisms. Treated seed lots frequently resulted in initial stands 20% to 40% better than untreated controls. Based on current information, *Apron* can be used successfully with both clay-based and humus-based pre-inoculants if directions are followed carefully.

Lime coating of legume seeds has also been accepted in some states as an aid to better stands. Newer lime coating processes seem to work well with both pre-inoculated and *Apron* treated seed.

Seeding Tools

Good hay-crop stands can be obtained by using a variety of techniques. Some are more successful than others, depending on local soil and climatic conditions.

Seeding equipment commonly used for grasses and legumes on a prepared seedbed include:

(1) *Cultipacker Seeder.* This machine works well for seeding legumes or small-seeded grasses on areas free of crop residue. Light-weight seeds – smooth bromegrass or wheatgrass – may not be well covered and smaller seeds may not be covered with the cultipacker seeder on areas having heavy crop residues.

(2) *Press Drill.* A drill which has press wheels following the seed tubes is best on fields with crop residue. A press drill also shows excellent results on plowed or clean, fallowed land if a uniform shallow seeding is made. They warn that light-weight grass seeds may "bridge over" in the drill box and not feed down the spouts.

(3) *Grain Drill.* On plowed or clean, fallowed land, a grain drill can be used without press wheels. Pack the field after seeding, but remember that packing can lead to erosion, under some conditions. "Bridging over" is also a problem.

(4) *Broadcast Seeder.* A broadcaster can be used for seeding forage legumes on plowed or clean fallowed land if seed is harrowed in, or gone over with a corrugated roller. In some areas, early spring broadcasting without covering is the accepted method for seeding red clover in fall-sown wheat.

Fluid or suspension seeding is a relatively new, but very effective, custom way of broadcasting seed uniformly over large acreages in a short time. However, cultipacking before and after seeding is a must with this type of seeding. Authorities generally agree that if seeding occurs immediately after the inoculated seeds are added to the suspension, there's no injury to the rhizobia.

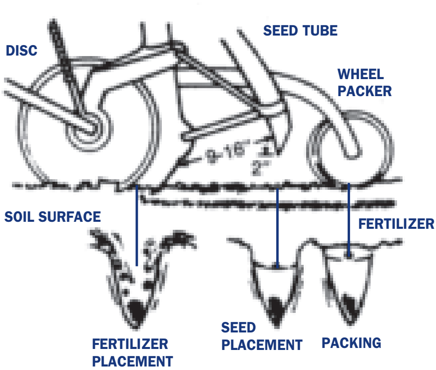
No-Till Seedings Gaining Favor

In many areas, seeding alfalfa or other legumes the no-till way either in small grain or corn stubble, or in sod, has gained momentum in recent years.

Several requirements for successful no-till establishment include:

(1) Competition from other plants must be eliminated.

Band Seeding Most Reliable



(2) Heavy thatch and plant growth tall enough to shade the soil surface must be removed.

(3) Protect the seedlings from insects, especially when seeding in sod.

(4) Soil fertility must be medium to high with pH about 6.5.

(5) Seed at the proper time.

(6) Use proper, well maintained equipment.

Seeding Forages with a Companion Crop

Small grain companion crops are among the oldest methods of getting weed-free forage the seeding year. However, recent research shows small grain crops compete with young seedlings for light, moisture, and nutrients.

Where oats or other spring grains are used as a companion crop, all forage experts advise using a variety that is short, early maturing, stiff-strawed, and non-lodging. Then reduce its seeding rate by one-half. Lodging resistance is of greatest importance. Many seedings are thinned or lost when lodged grain forms a tight canopy over the legume, sealing out light. Barley is especially susceptible to lodging and is not usually recommended as a companion crop. For best results where oats is used, remove as green chop, silage, or hay, just as the heads emerge from the boot. After harvesting oats, close clipping of stubble can markedly improve the legume seeding. Careful management after the oat crop is removed is also important. Red clover can be improved more than alfalfa by clipping. Trash should be removed from fields after clipping. Delaying clipping until late August is beneficial only if you have good rainfall and soil moisture.

Weeds develop quickly in unclipped fields. Heavy weed growth almost always reduces vigor and density of new legume stands, as well as reducing hay yields the following spring.

Ohio tests indicate stands usually are better when alfalfa is seeded in oats instead of in wheat. But for fall seeding, wheat is better than barley or rye. Wheat is sometimes superior to oats as a companion crop for red clover.

Eliminate That Companion Crop

Recently many hay growers throughout the country have turned to spring seedings without a grain crop, especially with legumes. Except where weeds have been a serious problem, this practice has meant from 4 to 5 or more tons the seeding year.

Researchers in Illinois, Michigan, Iowa, and Ontario found proper herbicides applied when alfalfa is a few inches high do a good job of controlling broadleaf weeds. This gets legumes off to a good start, eliminates the need for a companion crop, and gives 4 or more tons of top-quality forage the seeding year.

Forage stands established without companion crops are usually better and more productive in following years. When legumes are seeded without a companion crop, weeds are a problem and some means of control is necessary.

Good Weed Control Critical

Thus, good weed control with herbicides at establishment is critical to getting good hay stands.

Herbicides used for hay stand establishment can generally be classified as either pre-plant or post-emergence materials.

EPIC and benefin are pre-plant incorporated herbicides. That is, they are applied before planting and incorporated within the soil to a depth of 1 to 2 inches. If used at the proper rate and thoroughly mixed with the soil, these herbicides will control most of the annual grasses and many broadleaf weeds found in new legume seedings. Eptam also does an excellent job of controlling nutsedge.

Since these herbicides will severely injure seedling forage grasses, weed specialists stress they cannot be used in mixtures with forage grasses. Where grass-legume mixtures are to be made, you must rely on a spot emergence application of 2,4-DB for control of the broadleaf weeds but the grass weeds will be missed. However, for effective control, these materials must be applied when the weeds are small and the forage legumes are in the second to third trifoliate leaf stage.

Weed authorities further emphasize that forage legumes differ in their susceptibility to many of the herbicides mentioned. Alfalfa and bird's-foot trefoil, for example, are tolerant to treatments of EPIC, benefin, and 2,4-DB, but sweet clover and crown vetch are susceptible.

Before using herbicides on new seedings, be sure to check with local authorities for specific recommendations.

One final word: many new seedings have been severely damaged from herbicide residues, particularly triazines. Thus, plan your herbicide program for all of the crops in the rotation, not just the immediate seeding.

Manage Those New Seedings

Seeding year management can be important to the successful establishment of a new seeding, too. This includes insect control.

One excellent approach to a successful spring seeding is to seed on a prepared seedbed, eliminate the companion crop, control weeds and insects with chemicals, and remove the first hay crop the seeding year when the legume reaches the late bud to early bloom stage of growth. Normally with this program, three or more harvests may be made the year of seeding, depending on the length of the growing season.

In many areas of the U.S., potato leafhoppers can be very destructive on new spring seedings of alfalfa and other legumes. If leafhopper populations build up, there are several approved insecticides available to effectively control this pest on new seedings. However, daily inspections of the fields are necessary to detect its presence.

When weeds are a problem in spring seedings made without a companion crop, wait until the alfalfa is at the proper stage, second trifoliate, and apply post-emerge herbicides for best controls.

Establishing Bermuda Grass

Bermuda grass and other vegetatively propagated species require special attention for establishing stands. When preparing a seedbed, two factors are important: (1) sprigs (portion of stem or root used for transplanting) should be planted only in moist soil, and (2) the seedbed should be weed-free or weeds controlled immediately with herbicides after planting.

Planting should be fairly deep to insure continued soil moisture, but tops should be above ground. However, planting too deep may delay emergence and seems to increase spring damage by soil microbes.

Fertilizing as soon as stolons appear will help to hasten development and ground cover.

More Bermuda grass is propagated by planting sprigs than by seeding. Farmers generally have better success with this method. Poor seeding habits of coastal hybrid forage varieties such as Midland and Teft-44 types make it mandatory they be established from sprigs. Some farmers maintain on-farm Bermuda grass nurseries to insure having fresh planting material available.

Bermuda grass specialists say there are three major reasons for stand failures: (1) planting on areas that have stands of other grasses, (2) using dried out sprigs, and (3) grazing before grass is established. They suggest planting sprigs on a clean, moist seedbed free of other growing grasses. Use fresh sprigs with at least 3 nodes or joints. Plant sprigs the same day they are dug, or better still, the same half day. If not planted almost immediately, keep sprigs in cool storage.

CHAPTER 8

Growing

Facts on Irrigating Hay Crops

Automated irrigation requires expert management to be profitable. With a crop like alfalfa that requires 36 to 48 inches of irrigation a year in many dryland areas, the cost per acre can be significant.

Irrigation is the name of the game in many areas of the West, but studies also show irrigation can, and will, increase forage yields even in humid areas. And, with efficient water and crop management, irrigation specialists agree high returns on investments can be achieved. But many growers do not achieve the maximum potential income from crops such as alfalfa due to careless water management.

Nevertheless, west or east, one thing seems certain – a sizeable part of the U.S. irrigated acreage now is used for hay and pasture. In fact, recent census figures from 2008 show that over six million acres of land are irrigated for alfalfa dry hay, green chop and silage in the United States; today just one in five alfalfa acres remain non-irrigated.

Today, the depletion of water supplies and increased energy prices mean that modern irrigators must be conscious of environmental concerns while simultaneously controlling costs. To maximize their yields, progressive growers are increasingly turning to modern, low-pressure irrigation systems that require less energy to operate and conserve water. This is a fact backed up by recent USDA data showing a marked decrease in those acres irrigated by high pressure systems in favor of low pressure systems from 2003 thru 2008.

Automated irrigation systems are a major investment requiring careful selection and management by the grower to be profitable. In many arid regions the price per acre foot of water can be significant, and careful water management is required to achieve irrigation yield goals and farm profits. Alfalfa can require from 36 to 42 inches of irrigation per year in many dryland areas, so it's always important to speak with your local cooperative extension agency for regional irrigation recommendations.

Will Irrigation Pay?

Whether it pays to irrigate grasslands in humid and semi-humid areas depends on water supply as well as irrigation costs and returns, say agricultural economists. In most cases, the only way to determine the value of irrigation is to measure the change in total farm net income which results from the addition of the system. And before we can recommend it, we need evidence that irrigation will be profitable in nearly every year.

Irrigation authorities in the eastern states agree that irrigation on hay crops, especially alfalfa, may be profitable in hot, dry years. However, this depends on many things, including how long it stays dry, your water source, the availability of water for irrigation, and how much the feed would cost to replace the forage that didn't grow. It also depends on what it's worth to have the higher yields and quality that come with irrigation.

To get an idea of yield boosts possible with irrigation in humid areas, University of Minnesota economists visited 40 Minnesota irrigators in three counties. At that time, growers reported a threefold yield increase with irrigation. Average per acre yields for all producers in the three counties was less than 2 tons for all hay crops.

In other yield checks, with and without irrigation, conducted in a number of western states, irrigated hay generally out-produced dryland hay by a ratio of three and four to one. In California, forage specialist Vern Marble obtained over 16 tons of actual alfalfa hay on a field basis under irrigation taking 9 to 10 harvests per year. And in one recent maximum alfalfa yield research study in Arizona involving irrigation, researchers actually obtained a maximum yield exceeding 20 tons of alfalfa hay.

But improper irrigation of alfalfa may result in economic losses: (1) Improper irrigation practices hurt alfalfa yields more than diseases or insects, (2) more damage is done by over-irrigating, and (3) it doesn't make any difference which irrigation method is used, people will make errors.

Loss of alfalfa stands and the invasion of weeds, in either drown-out or dryness, are likely to be the biggest causes of economic loss with irrigated alfalfa. When we have irrigation problems in alfalfa, the problem is usually either under- or over-irrigation. When the question comes up about how much water is being applied, few producers know.

Irrigation in humid areas differs from that in arid areas where water is usually put on by flooding or ditching. The latter requires a heavy investment in ground leveling and soil deep enough to allow leveling plus minimum slope. In humid regions, water is most often applied by sprinkler systems and little or no ground leveling is needed. Sprinklers are also used to water hilly land that can't be leveled.

Irrigation Methods

In many western states, three irrigation methods appear to work well on alfalfa and other hay crops, agricultural engineers say. These include:

Sprinkler. Sprinkler irrigation, though not limited to them, adapts well to sandy soils or rolling land that is not conducive to other irrigation methods. Based on a 2008 USDA survey, Nebraska leads in the overall use of sprinkler irrigation followed by Texas and Idaho. Center-pivot irrigation systems continue to increase in use. These mechanized sprinkler irrigation systems, constructed of high-strength materials and of weight-reducing designs, are capable of traversing varying terrains and soil types with remarkable ease. The sprinkler devices utilized today are now capable of generating low intensity droplet patterns for the most difficult soils at energy conserving, operating pressures of 20 psi and lower. This can be accomplished while attaining uniformity of application efficiencies as high as 98%.

Sprinkler-type systems ordinarily demand a higher capital investment per acre than other systems, but this is generally offset by realized labor savings, energy savings and revenue from increased production. Earlier sprinkler systems also had a high labor demand, but today most systems are automatic to reduce labor. Mechanized sprinkler systems are the most efficient irrigation methods for larger fields and are an excellent means for starting new seedlings, experts say.

Border. In border irrigation, water is applied between parallel dikes or borders which may be up to 100 or more feet apart. Width and length of strips between borders depend on intake rate of soil, slope of land, and flow of water stream-size available, as well as width of machinery to be used. Borders are adapted to soils with intake rates high enough to allow soil to be wetted to a depth of 3 feet or more in 12 hours. Alfalfa crowns should not be submerged more than 12 hours since lack of air and a wet soil condition may weaken plants, making them more susceptible to crown or root rots and various leaf- spot diseases.

Corrugation. This system is used extensively on alfalfa is some areas. It is adapted to soils with low intalke rates and steep slopes, and requires less land preparation than the border method.

Throughout North America, developments in irrigation have been prompted by the desire or necessity to reduce labor, irrigation specialists agree. Sprinkler irrigation has been easiest to mechanize, so it has produced the most striking developments. Automation has also minimized labor for using side roll, boom types, and center-pivot systems.

The more recent, and also more sophisticated, center-pivot and “lateral move”, or traveling linear systems, are continuously moving, engineers say, first in a circle and the other in a rectangle. The lateral move or traveling linear system can be described as a side-roll wheel on the move. The lateral move has the ability to irrigate more acres in a rectangular field than does a center-pivot. However, the lateral move requires more labor than a center-pivot due to the need of detaching and reattaching the drag hose to the water source if a canal is not present. Precise control of center-pivot speed, direction of travel, and on/off control of end guns and other ancillary equipment is easily mastered with the use of GPS and programmable computerized controls. These center-pivot and lateral move systems can even be remotely controlled from a cell phone or laptop computer miles away.

One irrigation equipment dealer in the well drilling business for over 40 years expressed the opinion that it was very difficult to provide a rule of thumb rate for drilling wells in any specific area due to several conditions (region, soil structure, capacity, depth, etc). But he estimated that a 6-inch diameter test well might run anywhere from $15 to $30 per foot depth while the actual irrigation well can easily run $120 to $150 per foot depth and more.

Irrigation System Considerations

If you're considering irrigation, note these cautions from agricultural engineers: (1) irrigation alone won't produce the high yields needed to justify investment in an irrigation system. You must also plug in all other good management practices, and (2) you can't afford to be a part-time irrigator, viewing irrigation solely as "drought insurance." Irrigation requires a big investment, extra labor, fertility, precision planning for high yields, and most important – a good water supply.

Here are factors most irrigation specialists say you should consider before going into irrigation:

Water Source. An irrigation water supply must be big enough, good enough and legally available. In this regard statistics show that for all irrigation, about 53% of the water used comes from wells on farms, 32% from off-farm water suppliers, and 15% from on-farm surface sources.

Hay and pasture crops may need as much as 20 inches, and possibly more, of irrigation water a season to supplement natural rainfall, plus a waste factor for getting water to fields and into the root zone. For example, it takes 27,000 gallons for one inch of water on one acre, without any loss figured in. At the peak of the growing season, crops use 1/3 to 1/2 inch of water daily. Allowing for losses, you may need as much as 770,000 gallons per season for each acre of hay.

If you irrigate 24 hours a day, a good rule to follow is to be able to pump 10 gallons a minute for each acre, say University of Illinois agricultural engineers. If, for example, you plan to irrigate 20 acres, you'll need a water supply that furnishes 220 gallons a minute continuously.

Groundwater, when available at a reasonable depth, provides a good water supply. A small diameter test well is a good way to find out if you have ample groundwater source. After a test well is dug, pump it for several hours at desired flow rate to check capacity and recovery.

Most farm ponds are too small for large field irrigation. For a comparison, the average acre-sized farm pond contains only a million or so gallons of water. Also, you can only count on half of that for irrigation. The other half will be lost to seepage, evaporation and leakage in getting water to the crop. If you do use a farm pond, figure on needing 1-1/2 - to 2 acre feet of water for each acre you plan to irrigate.

Soil Type and Condition. Soil factors help determine the amount of water needed, soil scientists say. Some soils can absorb water faster than others. Given good management, any well-drained soil that absorbs at least 1/4 inch an hour can be irrigated. Your county agent, farm advisor, or soil conservation district technician can help you determine how much moisture your soil absorbs. If soil drains poorly, irrigation may make your drainage problem worse, and even cut yields. For example, a sudden rainstorm right after you irrigate could drown out the crop.

Fertility Status. High nutrient levels prior to alfalfa establishment are also a must to make irrigation pay, say North Dakota researchers. And producers must also soil test regularly and apply sufficient P_2O_5 and K_2O to maximize yields of aging alfalfa stands. In a 3-year study in their state, for example, the return above fertilizer costs exceeded $50 per acre when a combination of 50 pounds P_2O_5 and 100 pounds K_2O was applied per acre annually.

Management Ability. Irrigation isn't a "cure-all." Management, more than any other resource, as pointed out by California's Carl Schoner, makes an irrigation set-up profitable or unprofitable. Tilth – the physical condition of the surface soil – has to be maintained or soil will not absorb additional water. Variety selection, planting rates, fertility, and weed and insect control are all important. In short, irrigation is only one factor in shooting for higher yields.

Becoming an Irrigator. If you do irrigate, University of Minnesota and North Dakota State University specialists emphasize the need to plan your entire schedule. "Timing irrigation water applications to meet the needs of the crop is a crucial decision for each irrigator," reminds Hal Werner, a western extension irrigator engineer. "Effective irrigation," he says, "is possible only after monitoring conditions in the field and planning crop water use. Delaying an irrigation until crop stress is evident or applying too little water can result in substantial yield losses. Too much water," he concludes, "can leach valuable nutrients from the plant zone and result in added pumping cost."

Irrigation Costs. Up-to-date irrigation costs are hard to come by. But several years ago, Bob Perry, Univerity of Nebraska Aricultural Economist, estimated the average irrigation cost in his state to exceed $35,000 per quarter section for either flood irrigation or a sprinkler system. That's why top management is so critical and why irrigation in some areas has declined.

Over the long run, the critical investment of sprinklers and gravity flow systems will be fairly competetive, engineers in western states feel. As summed up by South Dakota State University Agricultural engineer, Fay Kerr, "Gravity systems are somewhat cheaper to set up, but the sprinkler system usually makes better use of water. Gravity flow systems often waste up to 30% of the water applied."

Total annual costs per acre will vary widely depending on water source, how far it's moved, the system used, and the whole range of fixed and variable costs. In Bob Perry's earlier studies, which include a range of new seedings and established stands, estimated annual costs per acre ranged from $63 to $98. With today's input costs, those figures could be increased significantly.

Install as a Unit

Above all, when considering an irrigation system, irrigation specialists say avoid developing it piecemeal. One piece depends so much on the other and investment is so high, they say, the system cannot be most profitable unless it is installed as a unit.

Finally, either sprinkler or gravity surface systems answer most irrigation problems. If a sprinkler system is used on sloping land, guard against soil, water, and plant nutrient losses by contour farming, and perhaps terracing. Level your land carefully if you use a gravity system. If top soil is shallow and rolling, leveling may turn up infertile subsoil, resulting in reduced water efficiency and lower than expected yields.

Forage Management to Maintain Stand

High forage yields, top quality feeds, and stands that last 4 or more years – if you have these, you have high hay profits with perennial crops such as alfalfa.

Today, as a result of new knowledge, chances are good that you can have all of the above. Why? (1) Improved varieties, (2) more know-how about forage fertilization, (3) greater understanding of root reserves and cutting management to maximize these reserves and (4) more effective insecticides and herbicides to control troublesome insects and weeds. Cutting management as related to forage quality was discussed earlier. In this chapter, we'll zero in on forage management to keep plants healthy.

Several factors are important to the management of perennial forage crops to keep them healthy and productive. These involve the location and amount of food reserves, cold and heat tolerance, winter hardiness, heaving resistance, drought resistance, and location of the growing area. Combining all these factors dictates the management practices necessary for optimum forage production and stand maintenance.

High hay profits with perennial crops like alfalfa depend upon high forage yeilds, quality feeds and stands that last four or more years.

Food Reserves and Storage Organs

Perennial forages store energy as total nonstructural carbohydrates (TNC). These food reserves are used by plants mainly to develop cold hardiness, to survive over winter and to initiate growth in the spring and after each cutting. These reserves are as essential as soil nutrients such as nitrogen, phosphorus, and potassium to the growth processes of the plant.

Where the food is stored varies with the plant species. In alfalfa and bird's-foot trefoil, for example, it's stored in the roots and crowns. Orchard grass and tall fescue store food in leaf sheaths and stem bases, timothy in its swelled basal stem internodes called haplocorms, and reed canary grass and smooth bromegrass in underground creeping stems called rhizomes.

To understand the importance of management as related to food storage, let's consider the growth pattern of one important hay species – alfalfa.

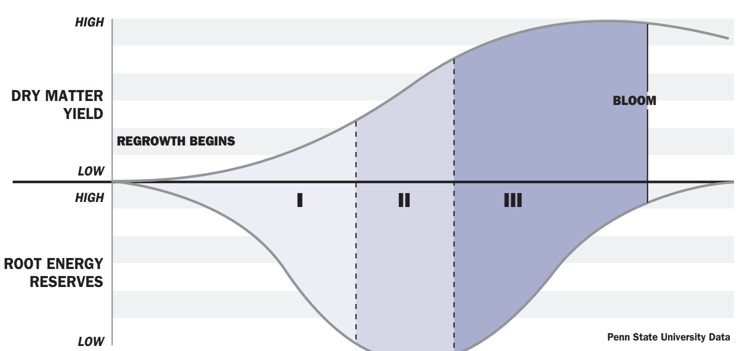
Reserves Supply Energy and Protein for Spring Growth

First Growth – When alfalfa growth starts in the spring, carbohydrates in the large roots and crowns are used to initiate new growth from small crown buds or underground stems. Depletion continues until the plant is approximately six to seven inches tall. At this time, carbohydrates are being synthesized in the leaves more rapidly than needed for growth. As a result, carbohydrate storage in the roots and crowns begins. Carbohydrate replenishment continues and reaches its highest level in the roots usually about full bloom. The changes that occur in root energy reserves and dry matter yield during one growth period of alfalfa are illustrated in Figure 9-1.

Regrowth – After the first crop is cut, preferably when flower buds have formed, the process of food reserve depletion and renewal is repeated for the new growth. Root reserves are not at the highest level at the bud stage of

FIGURE 9-1

Relative forage yield and quality at different alfalfa growth stages.



Changes that occur in dry matter yield and root energy reserves during one growth period of an alfalfa crop. Stage I – early growth: Stage II – plant are 6 to 8 inches in height; Stage III – plants reach maturity.

growth. However, plants can maintain a satisfactory level of reserves if harvest of at least one or the later cuttings is delayed until early bloom and careful management is practiced in the fall. Seasonal trends of available carbohydrates in the roots of alfalfa are shown in Figure 9-2.

Fall Management Important

In general, the period before the first frost is usually critical to forage survival, especially with alfalfa. The reason: at this time a large supply of food reserves is a "must" to assure winter survival and vigorous spring growth.

Also, harvesting shortly before a killing frost is known to weaken plants and cause winter injury. Why? Because alfalfa cut in late September or early October, in major northern alfalfa growing states, may produce 8 to 10 inches of new top growth that will be killed by frost before maximum storage of reserves can occur. When this happens, plants can go into winter in a weakened condition. And under average conditions the 4 to 6 weeks before the first killing frost is still a critical period.

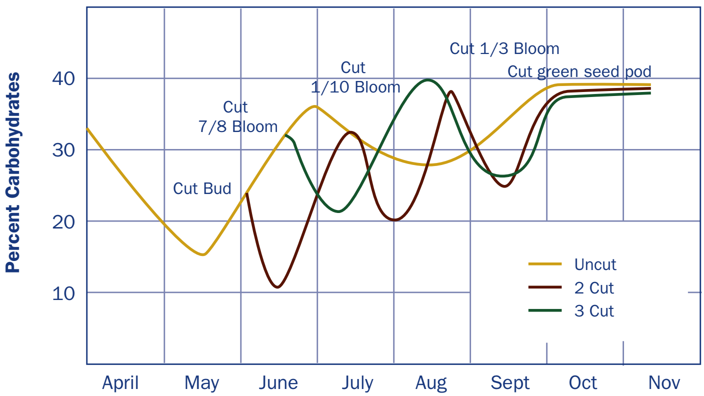
Recent research suggests that the recommendation to not cut during the fall "critical period" can be relaxed to allow greater management flexibility in many northern states. Furthermore, the concepts of a "critical period" are not always valid, particularly when you use winter dormant, multiple-pest-resistant varieties and maintain high soil fertility on younger alfalfa stands.

When to Fall Harvest

What, then, is the best fall management system to follow for alfalfa? There's no single answer. With newer, more winter-hardy and disease-resistant varieties, combined with higher fertility,

FIGURE 9-2

Carbohydrates Available in Roots of Alfalfa Plants



Seasonal trends of total availible carbohydrates in the roots of Vernal alfalfa at Madison, Wisconsin, with two cuttings at mature stages, three cutting at early maturity stages, and no cutting. Adapted from Smith, Dale. University of Wisconsin.

earlier and more frequent cutting or grazing is now possible. Agronomists know certain varieties can survive autumn cuttings better than others.

Researchers also point out that you can't separate fall cutting management from other harvest management throughout the year. Take the first cutting early, at late bud or the first flower, and fall management can be critical. On the other hand, delay first cutting to late bloom and when you cut in the fall is less important.

But to be safe, it's a good idea to either harvest early enough in your area to give the plants sufficient time to build up reserves before frost, or delay harvest until near or after a killing frost so there is little or no regrowth after cutting.

One caution – if you do make a late harvest, leave at least 4″ of stubble to help plants trap snow, which acts as an insulator to shield plants from cold weather. This helps reduce the freezing and thawing that causes heaving.

How about Winterkill?

Winterkill losses are another problem northern hay growers must contend with. These are generally caused by any one or a combination of three conditions:

1. Freezing of plant tissues
2. Heaving
3. Smothering

Here's how each affects over-wintering forages.

Freezing of Plant Tissues. Plant death caused by freezing temperatures results from ice forming in tissues. When living tissue is frozen, ice usually forms where water has been withdrawn from cell walls, and cell death is caused by dehydration. The ability to survive formation of ice crystals is called "hardiness."

Heaving. Alternate freezing and thawing causes wet soil to expand and contract. This action lifts the alfalfa crown and taproot up through the soil. This lifting tears small roots from the taproot and exposes the crown and root parts to potential wind and cold temperature damage.

Frost heaving is a serious hazard to legume stands, especially on level claypan soils with a silt loam surface. In wet weather, the silty surface becomes saturated with water which can't drain through the subsoil. When coupled with alternative freezing and thawing, this condition will result in severe heaving.

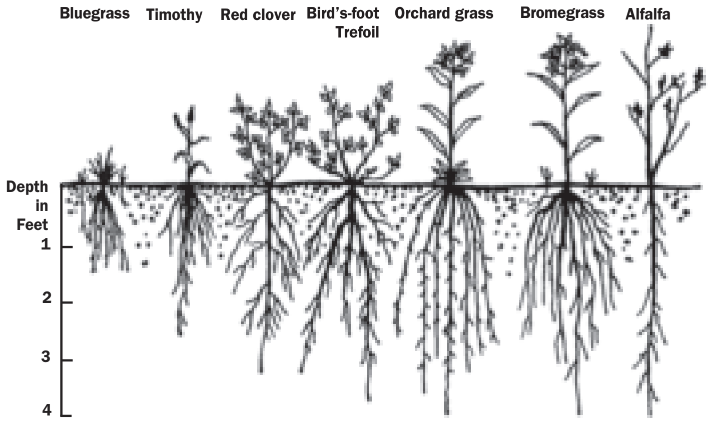
Smothering. According to Wisconsin's Smith, smothering injury occurs when ice sheets are maintained by temperatures that are low, but not low enough to directly injure the plants. By freezing, the nature of this smothering injury is both directly and indirectly a result of the accumulation of high concentrations of the byproducts of aerobic and eventually anaaerobic respiration at the crowns. Carbon dioxide is by far the most active single production of this toxicatin, Smith believes. And the longer the ice sheet encases and seals the plant, the greater the injury.

Use of Winter-Hardy Varieties

Selecting winter-hardy varieties

FIGURE. 9.3

Rooting Pattern of Forage Crops



adapted to your area is one obvious way to reduce winterkill losses. Although legumes fit a wide range of cold temperatures, they're more subject to heaving than grasses because of their root systems.

Rigid taproots hold legume plants above ground after heaving, exposing crowns and roots to drying and temperature damage. As shown in the rooting patterns of several forage crops (Figure 9-3), grasses have a fibrous root system which holds more soil and settles back after heaving. Thus, growing a fibrous-rooted grass with your legume on soils where heaving is likely to occur is one way to minimize forage losses due to heaving.

In Iowa tests, red clover and bird's-foot trefoil normally survived frost heaving better than alfalfa. Red clover and birds-foot trefoil have branching taproots; most alfalfa varieties have a long taproot.

Legumes in a legume-grass mixture, however, were less subject to heaving and had a higher survival rate than pure legume stands. Heaving in mixed legume-grass seedings ranged from slight to moderate, while damage to pure legume seedings ranged from moderate to very severe.

Fertilizer Winterizes Plants

Proper fertilization increases winter-hardiness, too. Healthy, well-fertilized plants have deep roots and are less likely to be heaved from the soil. They also have more leaf area for building up food reserves. Potassium is especially critical for keeping plants alive during the winter. Even in southern states, sub-freezing temperatures may injure or kill forages if potassium is deficient.

In a three-year Georgia study, Coastal Bermuda grass was severely winterkilled when high nitrogen rates were not balanced with potassium (see Figure 9-4).

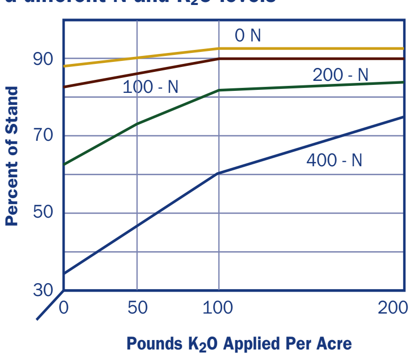
Losses ranged from 35% to 92%. Plots without nitrogen maintained stands regardless of potassium levels.

Canadian tests also point to the importance of balancing fertility levels with adequate potassium. Researchers there applied only nitrogen to an established timothy stand. Three years without potassium fertilization resulted in a 70% thinning of the stand. An annual application of 100 pounds nitrogen, 13 pounds phosphorus, and 83 pounds potassium per acre maintained both yield and stand, the researchers report.

How does fertilizer increase winter-hardiness of alfalfa? One way is by increasing levels of both starch and non-reducing sugars in the roots. Also, the protein content, both total and water soluble in the alfalfa crowns, was much higher in plots where fertilizer had been applied. The results obtained leave no question that high levels of lime and available phosphorus and particularly potassium, markedly promote winter survival of alfalfa.

FIGURE 9-4

Winterkill of Coastal Bermuda grass a different N and K_2O levels



Fall Topdress Aids Stands

Early fall topdressing (actually late summer) can improve growth of a weak stand. Stronger stands resist winterkilling more easily. New spring seedlings need to be topdressed in the fall to promote winter survival and vigorous spring growth. Purdue agronomists recommend fall fertilization of winter grains in which alfalfa will be seeded in the spring. Legume-grass seedlings in wheat need large amounts of potassium.

Managing Winter Damaged Stands

Even with good management, you can't completely avoid winterkill losses. But you can still get good hay yields even when winter injury is severe.

First, carefully examine forages for signs of damage after snow, ice, and standing water disappear. Sprouting of strong, healthy buds and new shoots indicate stands suffered little or no winterkill. Don't be too anxious to plow up stands where regrowth doesn't immediately appear, however. These crops may just be slow in getting started.

Many winter-injured alfalfa stands can be brought back to a productive life if first cutting is delayed. Cutting at full bloom gives plants time to heal their wounds and store foods in roots and crowns. The first harvest may be light and somewhat weedy, but the second crop is often back to normal.

Even if stands are badly injured, it might pay to keep a thin stand and get some yield, rather than reseeding and possibly getting no yield.

Oats can be drilled into first-year meadows to boost hay yields. If the field is to remain meadow a second year, grasses and legumes can be seeded with the oats.

Fast growing forages offer another possibility for getting extra hay in an emergency. Piper sudan grass, hybrid sudan grass, or a number of sorghum sudan grass hybrids are ready for harvest five to six weeks after seeding and a second cutting in as little as 25 days under high fertility and abundant soil moisture.

Reseeding in poor alfalfa stands generally isn't recommended. Stands that are thinned more than 50% should be replanted. However, you may want to fertilize and harvest any grass remaining in the mixture.

Winterkill Summed Up

Whether or not winterkill is really a big problem boils down to two main points – weather and management. Although an unusually hard winter may take its toll of forage stands, there are several things you can do to soften the blow:

1. Select winter-hardy varieties adapted to your area and cut at recommended dates.
2. Use a grass-legume mixture and provide good drainage on soils where heaving is a problem.
3. Keep stands healthy and vigorous by supplying a balanced fertilizer ration and lime when needed.

Cutting Management Important

As stated earlier, longevity of a perennial forage stand is related to cutting management, along with a sound fertility program. Frequent and untimely cuttings when food reserves are low will usually reduce the number of plants in the stand. And food reserves must be high in the fall in order to develop sufficient winter-hardiness and obtain vigorous spring growth.

With this in mind, let's briefly summarize cutting management recommendations for major legumes, both for the seeding year and for established stands.

Alfalfa

Seeding Year – During the seeding year, seedlings need a high food reserve in order to persist through the winter. Generally, all cuttings made within one year after seeding should be made no earlier than late bud stage. At least one of the later cuttings should be allowed to reach early bloom to build root reserves.

Established Stands – The number of cuts you take per year depends on where you live and how long you expect to keep the stand. In general, for northern areas, make the first cutting at full-bud to first-flower, later cuts at first-flower to ¼ bloom (normally 32 to 35 days between cuts).

When possible, avoid cutting during the 6-week period prior to the average killing frost date. If you do harvest during September to mid October, at least 45 days of regrowth should be allowed prior to cutting. For after frost harvests, leave a 4″ stubble.

Cutting management of an alfalfa-grass mixture should be based on harvest schedule of the legume.

Red Clover

The carbohydrate pattern of food reserves in red clover and alfalfa is similar, but the levels maintained in red clover are lower.

Seeding Year – Make first cutting before full-bloom. Red clover seeded alone in the spring can usually be harvested twice the seeding year. If seeded with a companion crop, normally one cutting the year of seeding is taken.

Established Stands – medium red clover performs best with 2 annual harvests. Take first cut at ¼ to ½ bloom and a later cut at ½ bloom. If there is good full growth, make an additional harvest after the first killing frost.

Bird's-foot Trefoil

The carbohydrate reserves in the roots of bird's-foot trefoil follow a cyclic pattern of utilization similar to that of alfalfa, but are maintained at a very low level during the growing season.

Seeding Year – Delay harvest until trefoil is in full-bloom, usually only one harvest possible. Maintain cutting height of 3 inches.

Established Stands – Take first cutting at early-bloom (usually a six-week interval). Allow four or five weeks of growth before first average killing frost. Maintain 3-inch cutting height. Research in Ontario, Canada, suggests that the "critical" fall harvest period of bird's-foot trefoil is about 10 days earlier than for alfalfa.

Perennial Grasses – How They Grow

While we normally depend on legumes for high yields, persistent stands, and quality forage, perennial grasses have an important place, too. When properly fertilized and managed, cool season grasses can produce five or more tons of hay equivalent per year. But to cash in on perennial grasses in your forage system, you must know how they grow and store food reserves.

The trends in production, storage, and use of stored food in many temperate perennial grasses are similar to those in alfalfa. However, the range in fluctuation of food storage varies with species. The amount of stored food declines with early spring growth and after cutting, and then increases until seed forms or the plants are cut. The lowest level of food reserves generally occurs during vegetative stages of growth and maximizes at heading.

Time and Height of Cutting

Time and height of cutting are important when designing management systems for grasses, either alone or in mixtures with legumes. For example, bromegrass and timothy can be severely damaged and killed by cutting during the jointing stage, which is immediately prior to head emergence. Researchers believe this is due to plant hormones produced by the plant during the jointing stage. These hormones limit initiation of new tillers. When the growing tillers reach boot stage the plant ceases production of the hormones and can be safely harvested. Orchard grass, tall fescue and reed canary grass will survive early harvest because they do not produce these same hormones.

At any rate, a good cutting management for most cool season grasses grown alone, is to make first cutting just as heads emerge from the boot. And while grasses differ in how they recover, later cuttings can normally be made five weeks after the first cutting. Raising your cutter bar to 4″ is important to speed up the recovery of new growth as the lower portion of the plant shoots is where plant reserves are stored in grasses.

Bromegrass, Timothy Problem in Mixtures

Authorities agree there's often an advantage for growing an alfalfa-grass mixture rather than a straight alfalfa for hay. Mixtures are often higher yielding, persist better, and are easier to harvest and cure than pure alfalfa stands.

But cutting alfalfa early for top quality makes it difficult to keep bromegrass and timothy in mixtures by the end of the first harvest year. Grasses are weakened by cutting at these early stages because food reserves are at a low level. Likewise, new crown buds have not been developed enough to elongate rapidly and to produce a rapid recovery growth. As a result, the second and third growths of fast growing alfalfa form a canopy over the grasses with little chance of survival. The problem is more severe with a three- or four-cut harvest system than with a two-cut system. On the other hand, orchard grass is compatible with alfalfa because it is more advanced in growth at the time of first alfalfa harvest, and recovers rapidly from lower leaves after cutting to compete well with the alfalfa.

And while the growth pattern of tall fescue, reed canary grass, and perennial ryegrass may differ from that of orchard grass, they also persist better with alfalfa under intensive management than either bromegrass or timothy.

Cutting Management for Bermuda Grass

So far we've emphasized management of cool season grasses. But in the South, Bermuda grass is the big hay crop. Cuttings for hay should be made when Bermudan grass is about 16-18 inches tall, and every four to six weeks thereafter. Permitting the grass to grow longer than six weeks between cuts in summer lowers quality, increases cutting time, and does not increase annual hay yields.

And six weeks may be too long between cuttings based on research in Louisiana. Researchers there say animals in their studies achieved maximum performance when consuming Coastal Bermuda grass hay no more than four weeks of age harvested in June and July.

Under any circumstances, allowing the last cutting to grow about eight weeks until the first killing frost in the fall will enable the grass to build up reserves to give more vigorous growth and better stands the next spring.

Several factors are important to the management of perennial forage crops to keep them healthy and productive. These involve the location and amount of food reserves, cold and heat tolerance, winter hardiness, heaving resistance, drought resistance, and location of the growing point.

Insects, Diseases and Weeds Can Spell Trouble

Just to survive, forages must have a remarkable capacity to compete, to adapt, and to endure a wide range of environmental conditions. Forage insects and diseases, as well as weeds, are in there competing to take their toll on high-yielding legume and grass stands.

Nevertheless, we know that losses in both yield and quality, due to the presence of forage pests, can be devastating.

Forage Insects

Forage insects, especially those attacking legumes such as alfalfa, can destroy a lot of hay – as much as 20% to 30% or more on a given cutting if they're present in large numbers. But management of alfalfa and other forage insects can be achieved, entomologists say, through the practice of integrated pest management, or IPM. Integrated pest management is accomplished by combining several tactics, such as biological, cultural,

Forage insects and diseases, as well as weeds, are in there competing to take their toll on high-yielding legume and grass stands. The challenge is to avoid losses in both yield and quality, due to the presence of these negative forage pests.

and chemical control, in a compatible manner to maintain pest damage below the economic injury level. The number of insects at which control costs exactly equal the benefits expected from using a control is called the economic injury level. To optimize return on investment, control measures are usually initiated before the economic injury level is reached. This "action threshold" or "economic threshold" is the pest density at which control measures are applied to prevent an increasing pest population from exceeding the economic injury level.

Control Early

A good control program aims at controlling insects before they reduce your forage profits. In short, "an ounce of prevention is worth a pound of cure."

For new seedings and established stands, it means checking your fields regularly for insects, then applying a control measure when the economic threshold has been reached. But to do this, you'll need to know which insects are giving you problems and identify specific control measures. To help you identify pests of one crop, alfalfa, The Certified Alfalfa Seed Council has published *The Alfalfa Analyst*, an excellent booklet with color plates that provides an identification guide to alfalfa insects, diseases, and nutritional deficiency symptoms for that crop. If you are an alfalfa grower, this publication should be a part of your library.

Depending on where you live, possible damage or other losses to your hay crops may come from any one of the following insect culprits:

1. *Alfalfa Weevil*
2. *Potato Leafhopper*
3. *Pea Aphid*
4. *Spotted Alfalfa Aphid*
5. *Blue Alfalfa Aphid*
6. *Clover Root Curculio*
7. *Meadow Spittlebug*
8. *Clover Leaf Weevil*
9. *Grasshopper*
10. *Alfalfa Caterpillar*
11. *Alfalfa Webworm*
12. *Alfalfa Blotch Leafminer*
13. *Blister Beetle*
14. *Sweetclover Weevil*
15. *Nematode*

Three-and Four-Stage Life Cycles

Insects have either three or four stages in their life cycles, entomologists report. Sucking insects, such as aphids, leafhoppers, and spittlebugs have three stages – egg, nymphs, and adults. But others pass through four stages – eggs, larvae, pupae, and adults.

Larvae hatch from eggs. After larvae feed and develop, they usually form a silken cocoon in which they pupate, or go through a "dormant" stage. Later the pupae become adults, which emerge to lay eggs and begin another cycle.

The use of resistant varieties, if available, good cultural control practices, and natural enemies are all helpful to control many problem insects, entomologists point out. But in many cases the use of insecticides (organic or non-organic) for control will be necessary.

Use Good Chemical Sense

Just remember, knowing how to handle crop protectants minimizes problems. To keep residues out of feed, meat, and milk, strictly follow label recommendations on types of chemicals, dosage, time and method of application and harvest delay intervals. Read and follow label instructions carefully. Also, keep in mind chemical recommendations change quickly. New products are introduced each year, and sometimes restrictions are placed on others. Insects may develop resistance to some insecticides, and this will also change recommendations. So keep in close touch with your local agricultural authorities for the up-to-date information on insect control in your area.

Alfalfa weevil larvae are usually full grown in three to four weeks, then they spin cocoons and pupate. Pupae are first pale green, later brownish. (photo courtesy www.entm.purdue.ed)

Insects that Attack Forage Crops

Alfalfa Weevil – Description: Still one of the most destructive insect pests on alfalfa in North America, even though parasites are currently contributing to its control. In fact, USDA entomologists estimate that in recent years, parasitic wasps protecting alfalfa fields from alfalfa weevil and the blotch leafminer may have kept at least $40 million in U.S. farmers' pockets. Newly-hatched alfalfa weevil larvae are pale yellow with black heads. In later stages they're light green with a white stripe down their back, with pale, less prominent white stripes along each side. Adults are pale brown snout beetles, with darker markings forming a distinct pattern on their upper surface. Older adults often appear darker and less distinctly marked.

Larvae are usually full grown in three to four weeks, then they spin cocoons and pupate. Pupae are first pale green, later brownish. New adults emerge in 10 to 14 days.

Damage: The alfalfa weevil is a foliage feeder. Larval damage starts with tiny holes in the terminal leaves. As the larvae grow larger, they move about the plants but usually feed at the upper tips of developing shoots. Heavy infestation will skeletonize all the leaves. Larval feeding often causes the field to take on a gray, frosted appearance.

To determine the need for harvesting or chemical control measures, it's necessary to regularly check each alfalfa field. Extension entomologists in most states and Canadian provinces have developed specific sampling procedures to assist you in making a management decision. When chemical control is necessary, a number of approved insecticides is available.

Potato Leafhopper – Description: Another of the most damaging insect pests on alfalfa and several other legumes. Adults are pale green, wedge-shaped insects, up to about one-eighth-inch long. Females lay eggs in alfalfa stems and on larger leaf veins. Eggs are tiny, slender and white. In summer they hatch, after six to nine days, into young nymphs. Nymphs are white at first, changing to yellow and then to pale green.

Damage: Young and adult leafhoppers pierce leaves and leaf stems causing severe stunting of the plants and yellowing or reddening of the foliage. Usually greatest damage is to third and fourth crops in late-June through August in a 5-harvest system.

Control: The application of an insecticide is the most common method to control the potato leafhopper on alfalfa. However, the need for chemical control is based on leafhopper populations and plant height. Thus, checking fields from mid June to August weekly for leafhoppers is absolutely essential.

Recently, alfalfa seed producers have developed alfalfa varieties with tiny hairs covering alfalfa stems and leaf surface areas. Seedsmen have determined that potato leafhoppers do not like to feed or inhabit these hairy varieties. It is believed that the hairs limit access to the plant by the leafhoppers. This trait has provided these varieties with potato leafhopper resistance. However, in extremely high levels of potato leafhopper populations, some chemical control may be needed.

Damage from the leafhopper is most severe when a crop is under moisture or fertility stress. Thus, good agronomic production practices, encouraging vigorous alfalfa, will limit the amount of damage caused by this insect.

Pea Aphid – Description: This insect has a soft body ranging in color from light to dark green. Nymphs are smaller, but resemble adults. Eggs glued to alfalfa leaves and stems are yellow-green when first laid, but soon turn black. Eggs hatch in April or May.

Damage: Pea aphids are most serious when weather is dry and cause damage by sucking plant juice which causes alfalfa to turn yellow and wilt. When heavily infested, tops wither and die. Spring infestation can cause first-cutting reductions, reduce vigor of second and third cuttings, reduce yield of seed crops, and shorten stand longevity. Stunted plants with small leaves and spindly stems are another sign of pea aphids. When alfalfa growth is retarded, weeds often take over and crowd alfalfa.

Spotted Alfalfa Aphid – Description: Spotted alfalfa aphids are tiny plant "lice," much smaller and more active than the common pea aphid. Spotted alfalfa aphids are straw-colored with black spots on their backs. They feed only on alfalfa and are most likely to be found on the underside of leaves.

Damage: Aphids suck plant juices causing them to wilt and sometimes die. The insect leaves a sticky "honeydew" on which a sooty black fungus grows, often leading to harvesting and handling problems. They are most severe in the arid areas of western and southwestern United States.

Both the pea aphid and spotted alfalfa aphid have many natural enemies, and many newer alfalfa varieties are showing some resistance.

Blue Alfalfa Aphid – Description: First found in California in the mid 70's, the blue alfalfa aphid is now found in several western and midwestern states. It is similar to the pea aphid in appearance, but can be distinguished by a bluish-green coloration in contrast to the yellowish or light green color of the pea aphid. The most reliable means for rapid differentiation of this species is to look for a dark band of color on each antennal segment of pea aphids. Such bands are not present in the blue aphid.

Damage: Blue aphids may cause serious reductions in yield and stand of alfalfa with high population densities. They cause severe stunting and a symptom called "crinkling" of leaves. The deformed leaves are gray-green in color without obvious yellowing or "chlorosis." There is little discoloration unless leaves and plants are actually dying.

Clover Root Curculio – Description: This is the most destructive root insect of alfalfa and red clover in the U.S. and Canada. The adult is a small, slender, dark-gray snout beetle about 3/16-inch long. It feeds on foliage, but is rarely serious in this stage. However, larvae can cause extensive root damage, especially as stands persist.

Damage: Implicated frequently as a major pest affecting production, stand density, and persistence of alfalfa and red clover as well as winter heaving. Usual damage includes extensive scarring of the outer root layers which provides an avenue of entrance for many disease organisms causing wilt and root rot.

Control: A 2-year rotation out of alfalfa or clover to a non-host crop should help to lower curculio populations in the sod.

Meadow Spittlebug – Description: Young nymphs are gray or brown, and spotted. Like leafhoppers, which they resemble, adults jump quickly when disturbed. Masses of white froth, or spittle, on alfalfa or clover leaves and stems are the telltale sign of meadow spittlebugs. Nymphs can be found inside spittle masses in April, May, or early June. They hatch from eggs laid in August or September.

Damage: This insect is an early spring pest. Soon after hatching, spittlebug nymphs secrete a liquid that is mostly plant sap. They force air through the liquid to produce spittle. They are then enveloped by the spittle and live in folded alfalfa or clover leaves where they suck plant juices. As they grow, nymphs enlarge the spittle masses and move to tender new growth on upper plant parts.

Other insects such as the clover leaf weevil, grasshoppers, alfalfa caterpillar, and alfalfa webworms can cause serious damage when populations are high.

Alfalfa Blotch Leafminer – Description: The adult is a tiny, dull-black humpbacked fly which emerges in the northeast U.S. and eastern Canada in late May from overwintering pupae on the ground.

Damage: Pinhole alfalfa leaf punctures made by the adult indicates the fly's presence. Eggs laid on, or in the leaflets, hatch into small yellow maggots that mine or tunnel within the leaflets, causing enlarged blotches. Most U.S. and Canadian researchers agree the main loss from infestations is a slight reduction in protein content due to leaf loss.

Population levels have declined dramatically in the Northeast. USDA entomologists attribute this reduction to parasites.

Nematode – Description: There are several species of nematodes identified in the U.S. and eastern Canada which can harm both legumes and grasses. They are tiny, soil-borne organisms that require professional diagnosis to determine their presence.

Damage: Varies with species. May reduce seedling stands, winter survival, and forage yields. Infested plants become stunted with few stems and small leaves.

Control: Crop rotation is the most economical method of control at present, according to Canadian researchers, although insecticides such as carbofuran may provide some protection.

Blister Beetle – Description: There are several species varying in characteristics commonly associated with alfalfa in western states.

Damage: Beetles cause no damage to the crop, but when present in sufficient numbers, dead beetles in alfalfa hay may poison livestock, especially horses, due to presence in beetles of a poisonous toxin, cantharidin.

Control: Avoid conditioning hay with a crimper to allow beetles to crawl out and disperse before baling. If blister beetles are observed in the field close to harvest, they can be controlled chemically.

Forage Diseases

Losses from forage diseases are hard to assess, but USDA and other pathologists now estimate that annual losses from diseases alone could approach $1 billion. They've estimated the average annual loss from diseases to alfalfa grown for hay at 24%. Studies show that, with the disease anthracnose alone, yields from anthracnose-resistant varieties were 10% higher than those of susceptible varieties. Losses to red clover grown for hay is believed even higher: 35%. From the time a crop is sown until it reaches maturity, authorities say, it is threatened by at least one disease and sometimes by several at the same time. There are several principles to the control of forage crop diseases. These include: (1) Use the best adapted, disease-resistant varieties, (2) Keep pH optimum and don't allow fertility levels to become limiting, (3) Control leafhoppers and other insect pests because these interact with diseases, (4) Clean harvesting equipment to prevent spread of diseased plants, (5) Maintain a good cutting schedule to assure adequate stored food reserves and healthy plants.

The use of fungicides to control forage diseases is generally impractical, authorities say. However, recent research has shown that treating seed with the systemic fungicide metalaxyl (*Apron-FL*) does provide good protection against present strains of Phythium and Phytophthora seed and root rot pathogens, and frequently results in improved stands and healthier plants.

Common forage diseases may be divided into three categories: bacterial, fungus, and viral. Here is a brief rundown of major diseases, mainly of alfalfa, by category:

Bacterial Diseases

Bacterial Wilt

Bacteria causing bacterial wilt in alfalfa enter the plant through wounds caused by weather conditions, insects, or harvesting equipment. Irrigation favors the disease because water can spread the bacteria, and excess moisture helps bacteria survive. Symptoms are most evident in plants older than two years.

The first symptom of bacterial wilt is stunting, accompanied by an unusual number of stems. Leaves turn yellow and woody tissues of roots and stems turn brown.

Bacterial leaf and stem diseases also occur on alfalfa in some years. Overall losses from these diseases are minor, but locally can be severe.

Fungus Diseases

Most diseases of forage crops are caused by fungi.

Fusarium Wilt

Researchers say the first sign of fusarium wilt is rapid wilting of stems on one side of the plant. Other symptoms are bleached leaves at the top of the plant, rose or pink-colored lower leaves, and brownish root rot extending to the taproot.

The fusarium wilt fungus survives long periods in soil so crop rotation is not an entirely effective control.

The disease particularly affects alfalfa, but a few other legumes are known to be slightly susceptible. Plant breeders have recently developed varieties resistant to this disease.

Phytophthora Root Rot

This disease occurs in wet, poorly drained soils during extended periods of rainfall or excessive irrigation, according to Minnesota specialists. You can spot it by digging surviving plants in areas where stands have been thinned. If taproots are rotted off, then Phytophtora was likely the cause. Yellowish-brown, rotted to the crown are other symptoms. Plant breeders have recently developed alfalfa varieties resistant to this disease.

Other seedling diseases caused by Phythium and Rhizoctonia organisms are frequently confused with Phytophthora.

Fusarium Root Rot

The first sign of this disease occurs in the leaves which curl at the edges, then wilt. Deterioration begins in the crown and extends down the center of the root. The internal taproot becomes discolored brown.

Since resistant varieties are not available, growers must depend on proper management to minimize stress. Rotating crops at least every three years serves as a control according to many specialists.

Anthracnose

Like many other fungus diseases, anthracnose is favored by hot, moist weather. A big clue to the presence of this disease is the diamond-shaped lesions with dark borders appearing on the lower portions of infected stems. As the disease progresses, it may girdle and kill stems, crown buds, and even the crown. The "shepherd's crook" is often observed in young dead shoots. Dead, straw- colored stems scattered through the field indicate infection and stand loss.

Pathogens can be transferred between fields on hay-making equipment. Thus, while growing resistant varieties is the best bet, good sanitation is also important to slow down the spread of this disease.

Verticillium Wilt

This disease of alfalfa was found for the first time in the northwestern U.S. in the late 70's and is now widespread in the major northern alfalfa growing areas from New York and Pennsylvania in the East to Wisconsin and Minnesota in the upper Midwest.

When the disease is present, usually on stands three years old or older, temporary flagging of upper leaves occurs on warm summer days. The lower leaves and shoots later wilt and become pale yellow, then finally bleached and desiccated. In the advanced stage, plants in the field are stunted with yellow then desiccated shoots and leaves. Stems often remain green after the leaves are killed.

Varieties with resistance or tolerance to this disease are now available.

There are a number of other fungus diseases that attack alfalfa, red clover, and other forage legumes and grasses, some of which can cause severe losses in localized situations.

These fungus diseases include: downy mildew, spring and summer blackstem, and common leafspot. They have received less attention by plant breeders, but will get more attention in the years ahead, authorities feel.

Viral Diseases

A number of virus diseases are known to occur on alfalfa and other legumes, but with the exception of mosaic, relatively little is known about their distribution and importance.

Mosaic

Green and yellow mottling on leaves or yellow streaks between the leaf veins is characteristic of mosaic. Plants may also be dwarfed during the second or third year.

The pea aphid is considered the primary spreader of this disease. Thus, specialists recommend controlling the disease by keeping aphids under control.

Disease Control Summary

Unlike insects, there is no practical chemical control for most forage diseases. In most cases, resistant varieties offer the most practical, and in some case the only approach to disease control. But, other good management practices help, too. These include regular crop rotation, sound seed, good fertility, timely harvest, and sanitation.

Weeds Reduce Yield, Quality

Low levels of almost any weed can be tolerated in a forage stand. Knowing at what point weeds begin to cause economic losses is the goal of weed management.

Weeds can cause losses in several ways. For example, controlling quack grass in alfalfa can significantly increase protein levels of the hay. Depending on the level of infestation, protein levels in alfalfa forage ranged from 12% to 18% with quack grass compared to 19% to 22% when the quack grass was controlled.

All of these factors – reduced protein content, reduced intake, lowered digestibility, and reduced palatability, as well as possible reduced yield and extended forage drying time – all spell bad news for the presence of many common weeds in hay crops.

It's not always possible to determine when chemical weed control measures are needed. Weed density, weed species present, stage of weed growth, and weed moisture must all be considered. And the strength of the hay stand is also important. For example, four to five alfalfa plants per square foot is the minimum population to even consider weed control.

Controlling weeds at the time of establishing a new seeding is the most critical and helps to insure long term weed control. This includes not only chemical control but good cultural control practices, such as adequate lime and fertilizer to maintain a vigorous, growing, dense stand. Over 95% of the weed control in a good, healthy forage stand comes from competition provided by the forage. In order to maintain a relatively weed-free forage stand, you should make sure the forage seeding gets off to a good start, by the use of disease resistant varieties, proper fertilization, insect control, and cutting management, as well as chemical weed control. If necessary, maintain the forage stand in a competitive state as long as possible.

Chemical weed control in established stands can still be an economically sound practice. Today you have more and better herbicides than ever before to get the job done.

Many herbicides are weed specific and crop specific, and recommendations vary from crop to crop and region to region. For the best help in your area, if you have a problem, check with your local agricultural authorities.

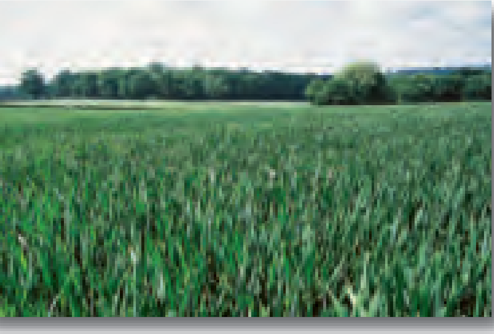
Harvesting

The Advantages of Cutting Hay Early

The profitability of forage-based livestock systems is largely dependent on the ability to feed high-quality forage. However, the quality of forage at feeding can never be greater than the quality of the crop harvested in the field. Therefore, being able to feed high-quality forage depends on the timeliness of cutting.

What Is Forage Quality?

Almost every nutritionist, agronomist, and farmer has a different way of describing forage quality, and these perspectives are driven by their field experiences. For example, in wet conditions, mycotoxins are more prevalent in forages, especially the forage grains. As a result, most nutritionists and agronomists currently would suggest that the presence or absence of mycotoxins is a large determiner of forage quality. Outside of personal experience, forage quality is defined by a number of factors. The American Forage and Grassland Council (http://www.afgc.org/), the National Forage Testing Association (http://www.foragetesting.org/), and the National Hay Association (http://www.nationalhay.org/) have all endorsed the following definition: Forage quality is "the extent to which a forage has the potential to produce a desired animal response" (Ball, D.M., M. Collins, G.D. Lacefield, N.P. Martin, D.A. Mertens, K.E. Olson, D.H. Putnam, D.J. Undersander, and M.W. Wolf. 2001. Understanding Forage Quality. American Farm Bureau Federation publication 1-01, Park Ridge, IL)



The quality of forage at feeding time can never be greater than the quality of the crop harvested in the field. Therefore, being able to feed high-quality forage depends on the timeliness of cutting.

What drives animal performance is a combination of forage nutritive value, forage consumed, and the presence of anti-quality factors. Nutritive value of forage is the product of forage digestibility and nutrient composition. The amount of forage consumed is determined by the availability, palatability, and passage rate with a specific forage.

Forage digestibility is the extent that forage is broken down and absorbed while passing through the gastrointestinal tract of the animal. Young, leafy plants are much more digestible than mature plant material. The nutrient composition of forage is defined by levels of specific chemical compounds such as protein, sugar, starch, fiber, fat, minerals, and vitamins. Water is also a nutrient, but water content varies widely in plant materials, so we express all nutrients on a dry matter basis to place different forages on a level playing field for comparison.

The availability of forage is both the amount of material in inventory as well as the amount of forage available to a specific animal at any given time.

Having a large inventory of high-quality forage is only of value if the animal has access to eat it. Palatability is agreeability or appeal of the taste, texture and smell of a specific forage to an animal. The palatability of a forage may be affected by the moisture content, leaf content, presence of weeds or insect infestation, fertilization or other environmental factors. Passage rate is the speed at which specific feedstuffs pass through the animal. Slow moving forages will fill the animal up and limit the amount of space available to consume new forage.

Anti-quality factors are any number of compounds in forages that may reduce animal performance, cause health problems, and even death. These anti-quality compounds can normally be individually identified and alone have detrimental effects on animal performance. The categories of anti-quality compounds include alkaloids, nitrates, tannins, cyanoglycosides, estrogenic compounds known as phytoestrogens, and mycotoxins.

What do all of these forage quality factors have to do with the timeliness of cutting hay? Simple – the point in time when a forage crop is cut for harvest determines not only the yield, but also the nutrient content, the potential digestibility, and the presence or absence of anti-palatability and anti-quality factors.

Some Cutting Facts

Given the myriad of factors described above, producing a quality hay crop would seem overwhelming. However, one clear fact rises above the rest in that forage quality, regardless of the type (e.g., legume, grass, or grain), is very closely related to maturity of the forage at harvest. Forage crops harvested as young, leafy plants will have greater protein and less fiber and lignin content than older, large-stemmed plants. The lower fiber and lignin content makes the young plants more digestible and pleasing to the palate and reduces the occurrence of anti-quality compounds.

Overly mature crops have three strikes against them in terms of potential animal performance, 1.) lower digestibility, 2.) less intake (due to slow passage rates and poor palatability), and 3.) less protein. Figure 11-1 shows the declines described when alfalfa was harvested at increasing maturity levels and fed to sheep. As can be seen in the table from mid-bud stage to full bloom, the alfalfa lost almost 1/3 of its protein, 16% of its digestible organic matter, and 15% of its intake potential. These types of losses are seen across animal species and forage types.

FIGURE 11-1

Effect of increasing maturity at harvest on chemical composition, digestibility and energy intake from alfalfa fed to sheep *(Kawas et all., 1990)*

Maturity at Harvest	Crude Protein	Acid Detergent Fiber	Neutral Detergent Fiber	Digestible Organic Matter	Voluntary Intake	Digestible Organic Matter Intake
	---------- % of Dry Matter ----------				g/BW kg$^{0.75}$	g/BW kg$^{0.75}$
Pre-bloom	21.1	30.2	40.5	63.3	77.9	49.2
Early bloom	18.9	33.0	42.0	62.4	76.5	47.9
Middle Bloom	14.7	38.0	52.5	55.4	66.2	36.7
Full bloom	16.3	45.9	58.5	53.2	66.2	35.5

Kawas, J. R., N. A. Jorgensen and C.D. Lu 1990. Influence of alfalfa maturity in feed intake and site of nutrition digestion in sheep. J Anim Sci 68:4376-4386

FIGURE 11-2

Effect or increasing maturity of alfalfa at harvest on purchased feed costs for high-producing 100-cow dairy herd.

Maturity at Harvest	Crude Protein	Acid Detergent Fiber	Neutral Detergent Fiber	Alfalfa Fed/Day	Purchased Grain Fed/Day	Purchased Feed Cost/Day
	----------	% of Dry Matter	----------	lbs.	lbs.	$
Pre-bloom	25.0	28.0	35.0	2166.0	1579.0	$165.60
Early bloom	20.0	33.0	40.0	1721.0	2024.0	$217.50
Middle bloom	17.0	41.0	46.0	1393.0	2339.0	$251.33

CPM-Dairy was developed at the University of Pennsylvania with contributions by Cornell University. The William H. Miner Agricultural Research Institute, and University of Maryland. The computer software program is specifically designed to evaluate the nutrient composition and economic viability of dairy cattle diets.

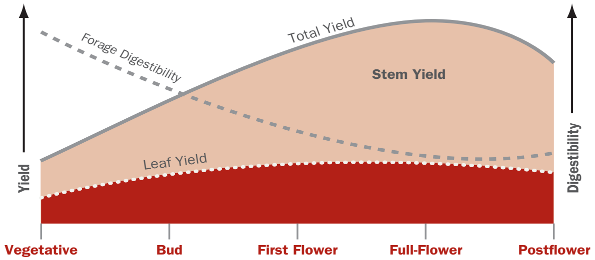
The economic benefit of harvesting hay or other forages earlier rather than later is fairly straightforward. In the example presented in Figure 11-2, alfalfa harvested at increasing maturity was substituted into the diet of a high-producing 100-cow dairy herd. Using the CPM-Dairy™ v3.08 Dairy Cattle Ration Analyzer, the economic impacts were assessed when half the dietary forage came from alfalfa hay and all other nutrient aspects were held constant except for the quality of the alfalfa hay. The results clearly show how dramatically purchased grain cost increases to compensate for the reduced quality of the hay when it is harvested at later maturity. Additionally, when the better quality hay is fed, the greater digestibility will likely allow for additional milk production, which would increase the marginal income over feed cost (IOFC). Having adequate forage inventory is crucial for this scenario as the cows will consume greater amounts of the high-quality alfalfa. If forage inventories are not adequate, purchasing additional high-quality forage may offset some of the economic advantages of early cut hay.

The key to early cut hay is the change in nutrient digestibility with increasing maturity. Figure 11-3 shows the relative changes in digestibility and yield of alfalfa compared to growth stage.

While the greatest advantage of early cutting is greater quality in terms of digestibility, there several potential advantages to early cutting forage.

FIGURE 11-3

Relative forage yield and quality at different alfalfa growth stages.



Adapted from: Orloff and Putnam. Balancing yield, quality and persistence. In: 2004 National Alfalfa Symposium and 34th California Alfalfa Symposium, 13-15 December 2004, San Diego, California, Department of Agronomy and Range Science Extension, University of California, Davis, CA 95616

First, rapid growth of plants caused by higher ambient air temperatures will cause more structural carbohydrates (i.e., cell walls) to be developed at the expense of non-structural carbohydrates (i.e., soluble cell contents such as protein and sugars). For this reason, spring growth of forages under cooler temperatures produces more highly digestible forage. By cutting hay early, the regrowth of second cutting hay will occur earlier in the season while temperatures are more moderate and promote greater digestibility in the second cutting hay. Second, harvesting hay earlier in the season may allow regrowth to take advantage of spring ground moisture and produce greater yields. Third, earlier hay harvest may allow more total cuttings through the season, which should generate greater total yield and overall quality.

Cutting Guidelines

When you should start cutting depends on many factors – acres to be harvested, forage species and varieties, equipment available, and, of course, weather. There is a variety of guidelines available across the U.S. for when to start hay crop cuttings: *(1) stage of growth/bloom, (2) regrowth from the crown or stem base, (3) predictive equation for alfalfa quality (PEAQ), (4) growing degree days (GDD), (5) scissor-cut samples, and (6) calendar date*. It is recommended that you consult with your regional Cooperative Extension specialists about the best method for your crop and area.

By Stage of Growth: This is the most commonly used method for determining both initial and subsequent harvests during the season. Most haymakers will agree that identifying stage of growth is superior to cutting at fixed intervals for obtaining consistent forage yields and quality. The greatest drawback to this technique is the potential lag time from identification of proper growth stage to actual harvest of the material. For example, most agronomists and nutritionists agree that for top quality, alfalfa should be cut between bud and one-tenth bloom. However, if you wait until one-tenth bloom, most of the crop will be harvested too late. To overcome this issue, many farmers will start harvesting at an earlier stage of growth such as mid-bud to guarantee that most of the crop is harvested by one-tenth bloom. Technological advances in harvesting equipment over the last decade have drastically reduced harvest times and widened the window of harvest opportunity. Figure 11-4 sums up general guidelines for cutting various cool season hay species across the U.S.

When grasses are grown with legumes, most specialists use the legume as the guide for cutting. However, the rapid growth of grasses can occur and the relative proportion of grass to legume within the stand must be considered when using *Stage of Growth* for harvest decisions.

Bloom is not always reliable for determining harvest date, because bloom is affected by season, moisture, and weather conditions such as cloudiness and temperature, and previous cutting conditions. Since bloom isn't always reliable, recommendations for alfalfa are to harvest first crop in bud stage and then cut every 35 to 40 days. The interval between harvests can be shortened or lengthened depending on the maturity rate of the alfalfa.

FIGURE 11-4

Stages of Growth to Harvest Optimum Nutrient Yields for Various Cool Season Legumes and Grasses, or Mixtures.

Species and Mixes	First Crop	Second Crop
Alfalfa-orchard grass	When orchard grass begins to head	Alfalfa bud to first flower
Alfalfa-smooth brome and other grasses	Alfalfa bud or fist flower	Alfalfa bud to first flower
Red clover	First flower to 25% bloom	First flower
Red clover with grasses	When grasses begin to head	Red clover first flower
Landino clover alone or with grasses	10% - 50% bloom of landino	Every 30 to 35 days
Bird's-foot trefoil alone or with grasses	10% - 50% bloom of bird's-foot trefoil	10% - 50% bloom of bird's-foot trefoil
Smooth brome, orchard grass or timothy	When heads emerge	Vegetative
Reed canary grass or tall fescue	Flag leaf to early heading	Every 30 to 40 days
Bermuda grass or bahiagrass	When 40 cm (16'') tall	Every 4 to 5 weeks

Adapted from: Albrecht and Hall. Hay and Silage Management in: Barnes R. R., D. A. Miller & C. J. Nelson. Forages, the Science of Grassland Agriculture, Fifth Edition 1995, Iowa State University Press, Ames, IA.

By Regrowth: After the first harvest of alfalfa, regrowth occurs from crown buds or axillary buds on stems. Using regrowth to determine cutting date should be when 60% of alfalfa crowns have buds or regrowth averaging ¾ inch. This system is often more reliable in the western irrigated alfalfa regions. In humid areas during dry seasons, this system does not work because buds may develop slowly.

By Predictive Equation for Alfalfa Quality (PEAQ): The PEAQ method was developed to predict the first harvest date for pure stands of alfalfa (Hintz & Albrecht, 1991) and uses the length of the tallest alfalfa stem and the growth stage of the most mature plant in the sample area to determine NDF content, and therefore, when to harvest. The system uses a calibrated stick for these measurements, and measurements should be made in at least five sampling areas within a field. The PEAQ sticks can be ordered through: Midwest Forage Association, 4630 Churchill Street, #1, St. Paul, MN 55126, phone: 651.484.3888. A demonstration of the PEAQ technique can be viewed on youtube.com at "http://www.youtube.com/watch?v=7Zroi5116dc". The PEAQ method can be used for determining second cutting harvest date also, but should not be used for third or greater cutting determinations.

Hintz, R. W. and K. A. Albrecht. 1991. Prediction of alfalfa chemical composition from maturity and plant morphology. Crop Sci. 31:1561-1565.

By Growing Degree Days (GDD): The GDD method (Cherney and Sulc, 1997) should only be used for determining first cutting harvest for alfalfa. Growing degree-days is an estimate of the amount of heat needed for plants to grow and develop normally and is measured between a minimum and maximum threshold temperature for a given plant species. For alfalfa growth, the minimum threshold temperature is 42°F (5.5°C) and the maximum threshold temperature is 110°F (43.3°C). So for alfalfa, the technique uses the following formula:

GDD42 = {(daily maximum temperature + daily minimum temperature) ÷ 2} – base temperature 42

If the high and low temperatures for the day were 75 and 55°F, respectively, then the formula would calculate as: **GDD42 = {(75 + 55) ÷ 2} – 42 = 23 GDD**

Growing degree days begin accumulating starting each January 1. For high-quality alfalfa, first cutting should occur between 680 and 700 GDD, which translates to between 38% and 40% NDF content. Using GDD is not recommended for second or greater cuttings of alfalfa or for alfalfa-grass mixed stands.

Cherney, J. H. and R. M. Sulc. (1997). Predicting First Cutting Alfalfa Quality. In Silage: Field to Feedbunk, North American Conference. February 11-13, Hershey, PA.

By Scissor-Cut Samples: The scissor-cut sample method relies on direct measurement of NDF in plant material collected from the field. Proper collection and handling techniques are critical to limit respiration losses prior to NDF determination. This technique requires more time and labor than other techniques. Further, labs assessing NDF content of fresh alfalfa samples using near-infrared spectroscopy (NIRS) must have appropriate databases and equations to provide accurate NDF determinations.

By Calendar Date: Picking a specific date to cut is the easiest management tool for deciding when to harvest. Using a calendar allows you to set up your cutting schedule and may be useful for the use of custom harvesters and operators. However, the calendar method does not allow for maturity variation in varieties, year, and locations and will likely limit overall forage hay quality.

How Often to Cut Forage

Early cutting hay and frequency of cuttings are closely related. In general, the earlier the first cutting and the more frequent the cuttings through the year, the greater the quality of forage harvested. However, selecting the proper interval after first cutting and between subsequent cuttings requires some trade-offs between top quality and maximum yield.

For alfalfa, longer intervals between cuttings where the crop reaches a maturity of 50% bloom will normally produce greater tonnage yields and promote longer stand life, but NDF content will likely reach 50% of DM, resulting in low-quality hay. Cutting at intervals where maturity has reached early bud or prebud will produce NDF content in the mid 30% range, which means very high quality, but tonnage yields and stand life will be lower and shorter. The absolute minimum interval is 30 days, but most growers will allow between 30 and 50 days depending on variety, weather and stand age. Using typical weather conditions in Pennsylvania, for example, a four-cuttings-per-year schedule for alfalfa will have first cutting at full bud to first flower and approximately 35, 38, and 45 days between subsequent cuttings.

The frequency of cutting cool season grasses is highly dependent on the specific species. In general, grasses do not tolerate more than three cuttings per growth year. And, typically, forage yields do not vary significantly between two and three times per growth year utting schedules. However, stand life changes dramatically with species. Tall fescues and reed canarygrass are typically more persistent than smooth brome or orchard grasses.

Minimizing Hay Loss

In the previous chapter, we described how harvesting early and frequently would improve the quality of the hay produced. However, every farmer has to realize that the opportunity to increase the nutrient content of hay ceases once the plant is cut and the challenge is to preserve as much of that nutrient value as possible.

Losses Begin at Cutting

The problem is that it's impossible to preserve all the quality found in the standing crop. In fact, as soon as the hay is cut, it begins to lose nutrients. If we understand these losses and where they occur, we can begin to reduce them. The one clear fact is that the less time it takes to get the crop off the field and into a stable form of storage, the greater the nutrients retained for feeding to the animal. For hay, this means that the more quickly the crop can be dried down, the fewer nutrient losses. For silage or baleage, the sooner that crop is placed in a properly sealed storage structure at the appropriate moisture content, the more nutrients are retained. As a percentage of the total crop, harvest-associated losses can remove a large percentage of the crop from the system (Figure 12-1). Here's a brief look at some of the losses, where they occur in the hay-making operation, and how big they can be.

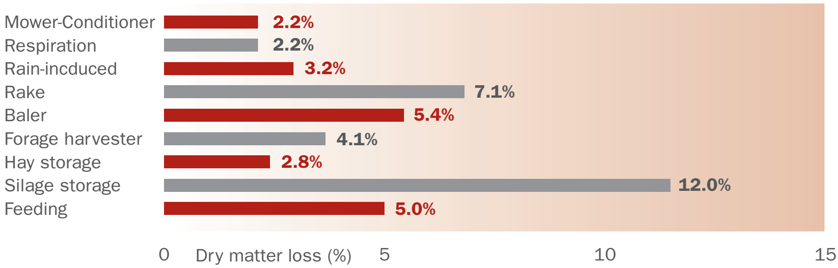
Metabolic Losses

Plant cells continue to function for a period immediately after cutting, so metabolic activities such as respiration go on.

Once forage is cut, the opportunity to increase nutrient quality is over. From that point on, all you can do is preserve the quality that's already there.

FIGURE 12-1

Estimated dry matter losses associated with harvest, storage and feeding for alfalfa

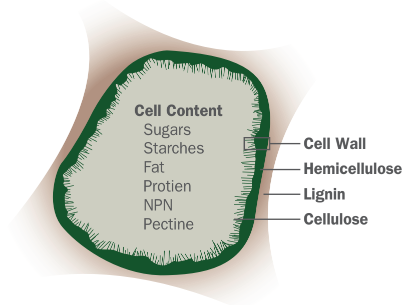


Adapted from: Buckmaster, D.R., C. A. Rotz and J.R. Black. 1900. Value of alfalfa losses on dairy farms. Transcript of the ASAE. 33(2):351-360.

Respiration, for example, will usually continue until plant moisture content falls below 40%; the result is a loss in sugars, starches, and other readily available carbohydrates. These losses are referred to as metabolic losses. Figure 12-2 depicts the location of these non-structural carbohydrates in the plant cell interior, where the aqueous environment will sustain respiration after cutting. Since these non-structural carbohydrates are essentially 100% digestible by animals, minimizing these losses is important for both forage quality and nutritional value. Metabolic losses from respiration can range from 2% to 16% of plant dry matter. There will always be some metabolic loss, since the plant will continue to respire once it is cut, but delayed dry down can dramatically increase these losses. For example, cutting forage in the evening will generally cause greater metabolic loss simply due to a longer period of respiration. Cutting and field drying forage during the day will allow crops to dry faster, reducing metabolic losses and resulting in higher-quality hay.

FIGURE 12-2

Diagram of a plant cell showing cell content and cell wall structure



Weathering Loss

Rainfall on cut forages can cause large amounts of weathering losses in hay. In humid areas, these losses can range from 4% to 60% of the forage dry matter. There are four ways in which rain causes losses during harvest: (1) wetter conditions prolong respiration, (2) leaching of soluble nutrients from dried plants, (3) heavy rains causing leaf shatter or loss, and (4) creating a condition favorable for unwanted microorganisms that cause fermentation losses during storage.

University of Wisconsin research has shown that one inch of rain on alfalfa one day after cutting will cause up to 10% leaf shatter and 15% total weather loss (Collins, 1985).

The extent of losses from rainfall will depend on the forage moisture at the start of rainfall, the number of rains and amount of rainfall, and mowing or conditioning treatments.

Collins, M. 1985. Wetting Effects on the Yield and Quality of Legume and Legume-Grass Hays. Agron J 77:936-941.

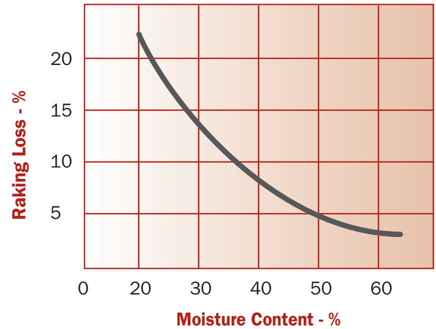
Mechanical Losses

Mechanical losses are those losses attributed to the machinery used in harvesting, storing and feeding hay, and chief among these losses is the leaf shattering or loss in legume hays. Leaf loss in legume hay is highly detrimental to nutritive value because leaves normally constitute 50% of the plant material but contain more than 2/3 of the protein and 90% of the sugars. The greatest factor affecting leaf loss is moisture content during harvest. Figure 12-3 shows the leaf losses from raking as moisture changes in alfalfa.

While raking can result in major losses (5% to 15%), conventional baler losses can add another 3% to 8%. In arid climates when alfalfa moistures at baling are between 15% and 25%, baling at night with dew or higher moisture has significantly less leaf loss than baling during the day (Collins et al., 1987). Packaging of alfalfa in rectangular bales causes about 2% to 5% leaf loss while packaging in large round bales typically results in 1% leaf loss at comparable maturity and moisture levels. Overall, the key element is proper timing at optimum moisture content to minimize losses.

FIGURE 12-3

Shattering Losses in alfalfa as influenced by moisture content when raked.



Source: Hundtoft. E.B. 1965 Cornell Univ. Agric. Engineering Ext. Bull. 364. Ithaca, NY.

Storage, Processing, and Feeding Losses

Losses during storage often result from microbial growth and subsequent heat buildup. For example, a large population of microorganisms is normally found on plant material in the field. During storage, if sufficient moisture is present, heat is generated from the metabolic activity of these bugs and continued plant respiration. Figure 12-4 indicates the changes that can occur to hay as temperature increases during storage.

While spontaneous combustion can be a concern with wet hay, the nutritive value of the hay is severely compromised due to reductions in protein digestibility and sugar losses. Furthermore, growth of molds and the resulting mold dusts and toxins can often contribute to human and animal health problems.

The amount and persistence of heat created in stored hay relates directly to the moisture content at time of storage. (Figure 12-5) Heating can

FIGURE 12-4

Problems associated with hay heating

Temperature (F)	Problem
115° - 125°	When coupled with high-moisture, molds and odors develop and decrease palatability
>120°	Heating reduces digestibility of protein, fiber, and carbohydrate compounds
130° - 140° _	Hay is brown and fairly palatable because of the carmelization of the sugars; however the nutritional value is reduced
> 150° _	Hay may turn black, spontaneous combustion is possible.

Source: McWilliams, 2006. Alfalfa Market News, Vol.4: Issue 7

occur in all hay unless it contains less than 15% moisture. Normally, a moisture content considered safe for baling is 20% or less, but even this can result in a 5% to 10% loss in dry matter.

Higher moisture content at baling can be beneficial because the leaf-to-stem ratio will be higher resulting in greater nutritive value. Each time hay is handled after storage, there can be losses of 1% to 10%, depending on the handling and feeding method. The method of feeding hay can dramatically change losses. Figure 12-6 shows the wastage of hay by cows with three types of feeding methods.

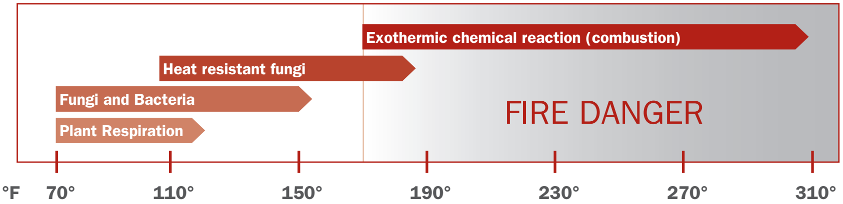
Economic Impact of Losses

The economic losses from marginal hay harvest, storage and feeding affect production costs in two different ways: direct dry matter losses, and indirect nutritive losses that affect animal performance. Below are examples of each type of loss.

(1) Alfalfa harvesting losses as high as 39% have been reported, with dry matter losses as high as 4% per day. If the potential annual yield of the standing crop is 5 tons per acre, a 39% dry matter loss results in a yield loss of 1.95 tons of hay per acre. If alfalfa hay is valued at $200 per ton, the economic loss is about $390 per acre. If the

FIGURE 12-5

Problems associated with hay heating



Adapted from: Henning, J.C., and H.N. Wheaton. 1993. Making and Storing Hay. University of Missouri Publication G4575.

FIGURE 12-6

Hay waste by cows as a % of material originally placed into racks.

Bale type & rack	% Waste
Square bale in rack	7%
Large round bale in rack	9%
Large round bale on the ground	45%

Source: Anderson, B., and Mader, T., 1996 University of Nebraska, "Management to Minimize Hay Publication G84-738-a.

potential yield of the standing first cutting is 2.5 tons per acre, a 4% yield loss per day results in a hay loss of 200 pounds/acre/day or $20/acre/day.

(2) Using the MILK 2006© decision software, which was developed by the University of Wisconsin to index alfalfa forage quality by estimating milk produced per ton of forage dry matter, we evaluated the economic impact of harvesting alfalfa at three different levels of management: *Excellent, Average* and *Poor.* A copy of the MILK 2006© decision software is available on the web at http://www.uwex.edu/ces/crops/uwforage/dec_soft.htm.

The three levels of management (Figure 12-7) are estimated to correspond to using the best hay-making procedures currently available with the following weather related adjustments: *Excellent* – favorable weather during harvest; *Average* – forage rained on once; and *Poor* – occurs after more than one wetting by rain.

Reducing Losses in Hay Making

With the goal of quickly drying a forage down and moving it into adequate storage, there are both old and new techniques for reducing losses during haymaking.

Harvest on Time

Chapter 11 was dedicated to the idea of cutting early to improve forage quality. When we consider weather damage, early cut hay with weather damage often will still have better quality than late cut hay without weather damage. (Figure 12-8) The digestibility of early cut alfalfa with rain damage is approximately 10% greater than late cut alfalfa without rain damage. The difference is the amount of cell wall, which is less digestible, laid down during the continued growth of the late cut hay.

FIGURE 12-7

Effects of harvest losses on quality for first cutting alfalfa yielding 4.1 tons of dry matter per acre and estimated milk production per ton and per acre, as determined using MILK 2006 decision software.

Management Level[1]	NDF, % DM	NDF digestibility, % of NDF	lbs/ton of DM	lbs/acre
Excellent	35%	60%	3,893	14,404
Average	40%	52%	3,339	11,685
Poor	46%	44%	2,724	8,389

1 Excellent - 10% DM loss, no reduction in forage quality; Average = 15% DM loss, 14% increase in NDF content, 13% reduction in NDF digestibility; Poor = 25% DM losses, 30% increase in NDF content, 27% reduction in NDF digestibility

FIGURE 12-8

Digestible dry matter of alfalfa hay affected by weather damage.

Cutting date	Treatment	Digestible Dry Matter (%)
10-Jun	No weather - heat dried	67%
10-Jun	Deliberate field weathering a/	57%
8-Jul	No weathering- heat dried	52%

a/ Water added or rain damage on all except two days of the 8 day curing period.
Source: Cornell University Data"

Mitigating the Weather Factor by Using Forecasting Tools

There's no secret formula for beating the weather, but knowledge of "weather aids" for determining a cutting date are essential. Choosing hay-making days is dependent on the equipment available. If there were no weather issues to contend with, how fast could you cut, field-dry and harvest hay with your equipment? One day? Two days? Three? Once you have an idea of your capacity to make hay, then use the daily and 5-day forecasts from you local weather stations to drive your decision to cut and harvest.

If you have a barometer, then you can use this additional information to complement a reliable 5-day weather forecast. Changes in air pressure are cues that weather is possibly changing. High and low pressure systems tend to move across the country in easterly directions. High pressure areas generally mean that air is moving downward and are associated with clear skies and cooler, drier weather. The barometer will show a pressure rise as a high comes into the area. Low pressure areas generally mean that air is gradually rising and are associated with cloudy and often rainy weather. The barometer will show falling pressure when a low pressure system enters the region.

Mowing and Conditioning

In order for a plant to dry quickly, it must be exposed to good drying conditions. The most important factors involved in this process are sunshine, humidity, and windspeed. While humidity and windspeed are not controllable, we can maximize the amount of sunlight by mowing hay early in the day, often just as the dew is off the crop. Cutting hay late in the day or evening only results in prolonged plant respiration resulting in increased metabolic losses.

Mechanical conditioning, whether with rolls or flails, can increase the drying rate. In general, by using a properly adjusted mower-conditioner, you can decrease the drying time by at least one day.

Drying Agents and Preservatives

Chemical hay drying agents and preservatives became popular in the mid 1980's, but have lost some of their popularity over the last decade as haymaking equipment and techniques have improved. The improved equipment and techniques have reduced drying times or allowed hay to be harvested at higher moistures, thus reducing the need for drying agents or preservatives.

Drying agents and preservatives were not developed to correct mistakes or disasters in haymaking. Their purpose is to enhance the dry-down process or limit the growth of spoilage micro-organisms under proper haymaking conditions. There is no silver bullet to making high-quality hay.

Chemical Drying Agents

Chemical conditioning of hay involves spraying chemicals on the crop during cutting that break down the waxy cutin layer on the wall of the stem. This treatment allows moisture to escape, and promotes faster drying with the drying rate of stems approaching that of leaves.

The primary drying agent used today is potassium carbonate (KCO_3). To improve the drying effectiveness of the KCO_3, additional chemicals such as sodium carbonate, sodium silicate, sodium propionate, methyl esters of fats, vegetable oils, and animal fat have all been used as amendments.

Chemical conditioners are more effective on pure stands of legumes such as alfalfa, bird's foot trefoil, and red clover, where there is a distinct difference between the surface characteristics of the stems versus the leaves. These agents are much less effective in grasses or mixed stands of grasses and legumes. There is a difference in the effectiveness of chemical drying agents by cutting and time of the year. First cuttings and late autumn cuttings do not respond as well to drying agents as second and third cuttings, even though drying agents reduce drying times in all cuttings. The reason for the limited effectiveness is the greater yield in the first cutting and the poor drying conditions in the late autumn cuttings. Drying agents work best when the conditions for drying are optimal. In the large heavy swaths of first cutting and late autumn, drying conditions are limited by airflow and weather conditions. It should be remembered that drying agents are not substitutes for mechanical conditioning of hay to promote drying. In fact, drying agents are more effective when used in combination with mechanical conditioning, especially rolls compared to flails.

Chemical drying agents are applied at the time of cutting either by a spray boom ahead of the cutter bar, or by spray nozzles mounted between the cutter bar and conditioning rolls. Recommended application rates normally vary from 5 to 7 pounds of the chemical powder in 30 gallons of water per acre. Commercial products will cost between $1 and $1.50 per pounds of active ingredient. The return on investment varies from farm to farm, and from cutting to cutting with the best returns on the second and third cuttings where drying conditions are better, thus ensuring more effectiveness of the product.

Baling Hay at High Moisture Content

There are two types of high moisture bales, 1) high moisture hay (25% to 30% moisture), and 2) baleage (50% to 60% moisture. Traditionally, the safe condition for baling hay was less than 20% moisture. However, at these low moistures, leaf loss could be great. Baling at 25% to 30% moisture ensures less leaf loss, but these bales must be treated with a preservative to inhibit spoilage organisms. These spoilage organisms include fungi such as Aspergillus and Fusarium, which can produce toxic metabolites that greatly reduce hay palatability, and heat-tolerant bacteria such as Actinomycetes, which produces the causative agent for Farmer's Lung Disease in humans (source:http://emedicine.medscape.com/article/298811-overview).

High Moisture Hay Preservatives

Organic Acids: The main organic acids used to preserve high moisture hay are propionic acid or a combination of propionic and acetic acids. In general, the higher the percentage of propionic acid in the mixture the more reliable the preservative. The target minimum is 60% propionic acid in a mixture. Dilute formulations are not effective and put more moisture into an already moist system. To determine a comparable cost between products, divide the cost of the product by the percentage of propionic acid in the product.

To be effective, organic acids must be applied at the proper rate depending on the moisture content of the hay, and must be uniformly distributed throughout the hay mass. They have been effectively used on both conventional bales and large round bales. Figure 12-9 indicates the recommended rates of actual propionic acid to be applied at baling for different moisture levels.

Whether the organic acid is a buffered product or not, skin irritation and eye damage can occur from exposure. Rubber gloves and protective goggles must be used when handling these products.

Acid Salts: Acid salts such as sodium diacetate have also been used on high moisture hay. Sodium diacetate, which is a dry formulated organic acid, inhibits growth of mold by elevating the acetic acid level in the baled hay. The reliability of these types of products is questionable, and there is limited published research on the use of acid salts as hay preservatives.

Anhydrous Ammonia: Anhydrous ammonia can be used as a preservative. When properly applied, it kills the fungi and bacteria that cause spoilage, in essence sterilizing the hay. Additionally, when applied to lower quality hay, anhydrous ammonia solubilizes some of the structural carbohydrate, hemicellulose, and lignin, thereby increasing digestibility. The residual ammonia in the hay at feeding can be a non-protein nitrogen source for ruminant animals such as cattle and sheep depending on the diet composition. The last two effects are limited to corn silage, low-quality grass hay, and corn stover.

FIGURE 12-9

Recommended rates for applying organic acid preservatives to hay

Hay moisture level (%-DM)	Rate (%) Dry weight basis	lbs. of acid per ton of hay
20 - 25%	0.5	10
26 - 30%	1.0	20
31 - 35%	1.5	30

C.C. Sheaffer and N. P. Martin Ext Folder 489, University of Minnesota

The process for ammoniating hay is to wrap a group of bales in plastic, inject anhydrous ammonia into the wrapped stack and allow the ammonia to equilibrate in the space and absorb into the hay. The suggested application rate is 30 to 60 pounds per ton of hay at 30% moisture. A general rule of thumb is to apply anhydrous ammonia at 3% of the as-fed weight of the material being treated. For more details on how to ammoniate hay go to:http://ohioline.osu.edu/agffact/0015.html.

There are limitations to the use of anhydrous ammonia that must be considered. First, handling anhydrous ammonia can be hazardous, and special precautions must taken to keep workers safe during the ammoniation process. Second, the process of ammoniating hay is labor intensive and can increase the cost of making hay by $20 to $40 per ton depending on the cost of ammonia, plastic and labor. Third, the bales must stay wrapped in plastic until feeding to trap the ammonia and keep the bales preserved. Without plastic wrapping, the sterilizing effect of the ammonia is only temporary. Lastly, excessive amounts of ammonia applied to high- quality forage can cause animal disorders, especially in dairy cows.

Bacterial Inoculants: Most bacterial inoculants are designed for silage preparation and have been adopted for use in making hay. The results of these bacterial inoculants are mixed. Early research showed little to no benefit from using bacterial inoculants on hay, especially if the moisture was less than 30%. More recent research has shown greater promise to reduce mold growth. The bacterium of interest is *Lactobacillus buchneri*, which was approved for use in animal feedstuffs in the late 1990's, and produces acetic acid during anaerobic fermentation. Acetic acid inhibits the growth of most molds and fungi, and as a result, reduces heating during storage and feeding. The effects are most pronounced in hay baled between 20% and 30% moisture. Application is normally recommended at cutting as mold growth can occur during the drying process.

Baleage or Silage Bale Preservatives: Silage bales are similar to high-moisture bales, except that they are baled at much higher moisture levels (50% to 60% traditionally). The crop is frequently pre-cut to a smaller particle size to make more densely-packed bales for improved fermentation. To undergo fermentation, silage bales must be wrapped in order to exclude oxygen and prevent harmful mold growth and spoilage. Individually wrapping of bales in plastic or placing them in tight-fitting plastic tubes are the predominant methods used when making baleage/silage. Being able to harvest the hay crop at a very high moisture has been beneficial in humid areas of the U.S., where traditional dry haymaking is problematic. The quality of properly made baleage is comparable to the equivalent dry hay or hay crop silage. The major challenge of baleage is the prevention of mold growth and spoilage during storage. It is highly recommended to use a preservative in making silage bales.

The main silage bale preservatives are bacterial inoculants, which were developed for use with chopped wet/wilted forage that was ensiled in upright tower silos, bunker silos, or plastic bags. Application normally occurs at cutting, and time from baling to wrapping should be minimized to reduce the growth of aerobic molds and fungi.

Supplemental Hay Drying

Supplemental hay drying with or without heated air, in the mow or in batch or wagon dryers, has been used for decades. Very popular in the 50's and 60's, by the late 70's, high labor and fuel costs made drying hay with supplemental air or heated air less attractive. Today, very little supplemental hay drying occurs as improvements in harvesting equipment and technology can produce higher quality hay without the need for supplemental drying.

Measuring Moisture in Hay

Throughout this chapter we've stressed the importance of knowing the moisture content of your forage to minimize harvest losses and assure safe storage. Hay harvested and stored at too high a moisture content will result in spoilage and possible spontaneous combustion. An accurate measure of moisture is essential for the proper use of chemical preservatives. Harvesting and handling hay when it is too dry results in excessive leaf loss and reduced feeding value in addition to the dry matter loss. And, of course, harvesting forage for silage at too high or too low a moisture content results in improper fermentation which reduces feeding value.

For centuries farmers have relied on their sense of feel and experience to estimate moisture in hay. Unfortunately, even with the most experienced growers, errors were often large and the results a disaster.

Today, moisture testing devices are becoming a much more common tool used by forage producers. Moisture testers on the market are of two general types, those utilizing heat, and those utilizing electricity. Each has advantages and disadvantages. Forced heated-air drying units are accurate and easy to use. Wet forages or feeds are weighed, dried, and reweighed, and the moisture content either read directly from the scale or calculated. The main disadvantage is the time to complete the test and need for a power source to run the unit. The two main forced heated-air dryers are the Koster Moisture Tester (http://www.kostercroptester.net/), and microwave ovens. Microwave ovens provide a quicker dry down than the Koster, but samples can become burnt and catch fire if not properly monitored. For the proper procedure on the use of a microwave oven for testing moisture, please go to: http://www.abe.psu.edu/extension/factsheets/i/I106.pdf.

Electronic moisture testers, on the other hand, are fast. The hand-held versions can be taken directly to the field or feeding area, and are relatively easy to use. But they're generally expensive in comparison to the forced heated air drying units. The hand-held moisture testers require that the hay in the windrow be compressed to provide an accurate measurement. Recent advancements in technology now allow for mounting of electronic moisture testers directly on baling or chopping equipment, providing real-time determination of moisture, and instantaneous determination if hay preservatives need to be applied.

CHAPTER 13 Harvesting

A Look at Hay Harvesting Equipment

For centuries, haying tools consisted only of simple scythes and pitchforks. Today it is possible to feed hay that has scarcely been touched by human hands. Mechanization began with cutterbar mowers, the harpoon-type fork for unloading hay in the barn came in 1864, followed by the hay loader in 1874 and the side-delivery rake in 1893. Yet haymaking remained a labor intensive and time-consuming job for nearly half the next century.

The New Age of Haymaking

Perhaps the greatest milestone in hay making was Ed Nolt's invention in the late 1930's of the first successful automatic pick-up baler developed by New Holland during the 1940's. The first production New Holland model 73 baler revolutionized the industry by eliminating the tiresome, sweaty job of forking hay onto the wagon and then into storage. Quickly replacing the large and cumbersome three- and four-man, hand-tie balers, over 20,000

In centuries past, haying tools consisted only of simple scythes and pitchforks. Today it is possible to feed hay that has scarcely been touched by human hands. (Courtesy www.safran-arts.com)

New Holland balers of this original design were manufactured over the next several years. The success of New Holland continues into the modern era with over 700,000 small square balers and over 200,000 round balers produced since then.

Scientific Haying Machinery

Several factors catapulted the new age of hay making. Credit is shared by new crop varieties, modern fertilizer, timely cutting, university research, and advanced haying machinery. Improvements in haying tools have given hay making an entirely new look; this chapter provides an overview of today's haying tools and their advantages. It also provides tips on how to get the most from your haying equipment.

The Fundamental Science of Hay Drying

Fundamentally, plant plant physiology provides the function of respiration once a crop is mown. Respiration allows oxygen to enter the plant where carbohydrates are broken down and moisture is expelled through the stomata. This biological process provides a drying effect on the mown hay; moisture will decline to 60% or 70% before the stomata begin to close. Respiration consumes carbohydrates, resulting in dry-matter losses. Quick drying preserves nutrient value. To hasten the drying process and produce the highest value feed, mown hay laid down at 80% to 100% of the cutting width insures that sunlight is able to act upon the leaves, driving the drying process.

Benefits of Mowing Without Conditioning

It goes without saying that mowing without conditioning has potential benefits for many producers. Mowers can be purchased at lower initial cost and have lower operational costs compared to mower-conditioners. Growers who produce only hay for silage requiring a moisture level of 65% to 72%, and growers in southern regions with favorable drying conditions for grass-hay production also benefit when making dry hay. However, southern producers

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frequently ted, fluffing the hay to augment drying, which offsets some potential savings. Today, even in northern regions where crops and climate conditions present unique drying challenges, many producers harvesting hay as silage mow without conditioning.

Sickle Mowers

Simplicity and economy keep sickle bar mowers popular; improved over the years to include more durable sections and carbon steel guards, these mowers are a mainstay of traditional and smaller producers where conditioning is not required when curing hay. Requiring low horsepower to operate, they are well suited to compact and utility tractors, making them ideal for small acreages when tractor horsepower is limited. However, productivity is limited to 4 to 5 acres per hour. Reduce your operating speed in heavy dense crops to prevent plugging and keep sickle knives sharp and belts properly tensioned to get the most from sickle mowers.

Disc Mowers

Disc mowers were developed in the late 1960's for cutting in tough conditions that often plugged sickle bar mowers. The modern disc mower is the standard for today's hay producers large and small when conditioning is not required to cure hay.

The disc cutter bar mows fine grasses as well as grass with wet or dead undergrowth, without plugging, slicing through ant hills and gopher mounds without damage. Plants are cut by high-speed rotating knives, effortlessly slicing through dense and tangled crops more easily than the reciprocating action of sickle bar mowers. Free-swinging knives, cutter bar breakaway and gear train protection systems prevent damage, providing higher reliability than sickle bar mowers. A variety of cutting widths is available from 5 feet to 10 feet with productivity from 5 to 10 acres per hour depending on model.

Conditioning Hay to Dry Quickly

Many producers today have chosen mower-conditioners; conditioning acts mechanically on the mown crop to improve the drying rate, making it possible to harvest sooner than a non-conditioned crop. Once moisture levels have dropped and plant respiration ceases, the closing of the stomata traps the remaining moisture, further drying slows significantly. Conditioning provides openings to the plant's structure to provide an exit path for moisture, allowing drying to continue at a faster rate. Today the most prevalent conditioning systems are roller and flail type, however other systems referred to as super-conditioners are also available.

Mower-Conditioners

Mower-conditioners combine cutting and conditioning into one operation. First developed by New Holland in 1964, the Haybine® mower-conditioner featured a sickle bar with pickup-reel combined with intermeshing rollers to gently crimp the hay. Nearly 50 years later and the original New Holland Haybine® mower-conditioners still lead the industry for smooth, clean cutting, and plug-free conditioning.

Full-lateral flotation permits the header to hug the ground over uneven terrain. An adjustable, variable-speed reel keeps the cutterbar clear and provides smooth, continuous flow of material to the rolls. Under-serrated knives provide fast, clean cutting in a variety of conditions. Heat-treated steel guards offer long life and reduced maintenance.

A variety of machine cutting widths is available to match the size of your hay harvesting operation. The most popular sizes are the 7-foot and 9-foot versions; however, larger units with several wider cutting widths are available.

Disc Mower-Conditioners

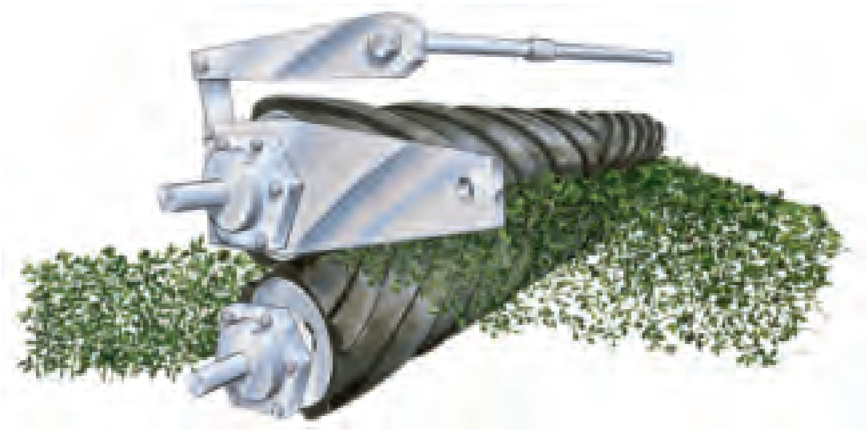
The addition of chevron-design intermeshing rubber rolls or tapered flail conditioning systems to the disc mower permits conditioning the crop when cutting. The crop can be laid down in a wide swath, or windrowed for later harvesting. Several sizes are available from 9′ 2″ up to 15′ 7″. A lateral-header-flotation system suspends the cutting head independently of the trail frame. The header glides over the ground following the terrain to get more crop, lessening disc and skid shoe wear. The advanced Shock-Pro™ hub normally protects the cutterbar gear train from damage in the event of contact with an obstruction. The MowMaxx® and MowMaxxII® cutterbars provide a lower profile than previous generation cuttberbars, slicing easily under down and tangled crops. New Holland disc mower-conditioners allow you to mow about as fast as you can drive; productivity increases are normally double that of a similarly-sized sickle mower-conditioner.

Self-Propelled Windrowers

With the widest cutting widths available, self-propelled windrowers are the pinnacle of high speed and capacity cutting. Self-propelled windrowers turn quickly on headlands mowing up to 19 feet of hay with each pass. Most cutting heads feature roller hay conditioners as standard equipment. Hydrostatic ground and header drive systems provide ultimate control while mowing, allowing infinitely variable ground speeds, and the ability to vary header speeds to match crop conditions for the cleanest possible cutting.

Roll Conditioning Systems

Roll conditioning is the crimping of stems and gently scuffing away of the protective wax from the plant's cuticle layer. Traditionally roll conditioning is considered the most versatile system capable of providing very gentle conditioning of delicate legume crops as well as aggressive conditioning of tall cane-grass crops. Rubber, chevron-intermeshing rollers are well established as the premier choice for alfalfa hay production. The chevron rubber roller is gentle on the crop, preserving leaves, while providing adequate conditioning. Rolls made of steel are often more aggressive and are well suited for tall cane-grass, winter forage crops, or when mowing in very abrasive, high-wear conditions. Conditioning system designs with very aggressive roll



patterns, abrupt sharp lugs, or extremely close roll gap may contribute to high field losses due to over-conditioning.

Adjusting Roll Conditioners for Performance

To get the most out of your roll conditioning system, proper adjustment of the roll timing, gap, and pressure is essential for both performance and longevity.

Roll Timing is the clearance between the lugs and valleys of upper and lower roller. Adjust the timing to provide equal clearance on the front and back of the lugs as they turn together so that stems are crimped without shattering. If the roll timing is set incorrectly, the roller lugs may touch, greatly increasing power requirements, roll wear, and field losses.

Roll Gap is the vertical clearance between the upper and lower roll, which is adjusted to provide that stems are compressed. To determine roll gap setting for your conditions, first determine the average thickness of crop stems by evaluating your crop, then adjust your roll gap to a setting just slightly smaller than this dimension. The traditional roll gap setting for alfalfa is approximately 1/8". However, this may vary slightly depending on the variety.

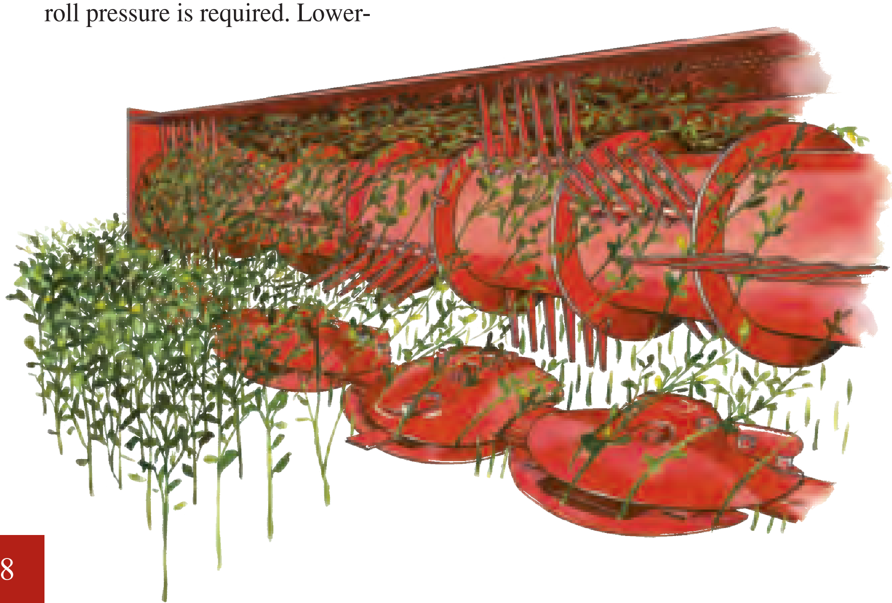
Roll gap is easily verified by manually turning the conditioner rolls and passing a rolled cylinder of aluminum foil through the rolls.

When adjusting roll gap, adjust the ends of the upper roller so that the rolls are parallel; a roll-pin punch may be used as a gauge to ensure the gap is set equally across the rollers. Roll gap is easily verified by manually turning the rolls and passing a rolled cylinder of aluminum foil through the rolls; the foil should be bent and crimped, but not completely flattened or crushed in any areas. To quickly check roll gap in the field, a plant stem may be used as a gauge; a slight friction should be felt as the stem is slid between the rolls.

Roll Pressure is the squeezing force applied to the crop as it passes though the rolls. To achieve best possible performance, increase roll pressure gradually by turning the crank until over-conditioning becomes evident; then back off the pressure slightly. Roll pressure setting should be varied based on the volume of crop passing though the conditioner to provide uniform conditioning throughout the crop. Early in the harvest season, when yields are at their peak, an increased roll pressure is required. Lower-yielding late season harvests require less pressure to provide adequate conditioning.

Flail Conditioning Systems

Flail conditioning strips away the protective wax from the plant's cuticle layer by passing the crop over a spinning rotor equipped with flails which carry the crop, scuffing it against an adjustable hood. Flail conditioning systems are most frequently used in grass hays because the more robust grass stems are more readily stripped of the waxy layer. Alfalfa crops may also be mown for silage using flail conditioning when the conditioning intensity is adjusted to minimize leaf losses; however, the conditioning effect is often inadequate when producing dry alfalfa hay. Flail conditioning systems are not recommended for use in tall cane-grass crops; these crops can become entangled on the rotor, substantially increasing power consumption and contributing to poor machine performance.



Adjusting Flail Conditioners for Performance

To get the most out of your flail conditioning system, the proper rotor speed and hood clearance are essential. A high rotor speed is normally reserved for grass crops; a lower speed will provide more gentle handling of legumes, preserving delicate leaves. To achieve the best possible performance, gradually lower the hood, moving it closer to the rotor, increasing the conditioning intensity until over-conditioning is evident, then reduce the intensity slightly. In conditions where more aggressive conditioning is desired such as heavy grass hays, a textured hood liner may be fitted to provide additional scuffing action on the crop as it moves across the hood.

Between Cutting and Packaging

While mowers and mower-conditioners make short work of acreage, the parallel bar rake, rotary rake and windrow mergers are widely used to turn the hay for speedy field drying, and to make windrows suitable for efficient harvest.

Rolabar® Hay Rakes

Two different widths are available, 8½' to go with the conventional 7' to 9' mower or mower-conditioners and a 9½' width suited for 10' and larger mowers or mower-conditioners. Special tandem rake hitches allow rakes to be pulled together, reducing raking time by one-half – either placing two swaths into two individual windrows for small square balers or two swaths into a single large windrow to match the capacity of the modern baler. They are available in PTO, ground or hydraulic drive, either trailing or mounted. Unlike ground driven models, PTO and hydraulic drive models allow the operator to vary the basket speed independent of ground speed to match crop conditions, providing cleaner raking.

Unitized Hay Rakes

Another raking concept for large acreage hay producers is the center delivery, Unitized Rake with twin Rolabar® rakes mounted on a single frame. The operator can hydraulically control basket width, angle, height, and conveniently open and close the rake from the tractor seat. The baskets are 10′6″ wide and effectively match the cutting widths of the larger mower-conditioners and swathers. The rake is capable of combining two 16′ windrows, or raking a 27′ swath of material into a fluffy 6′ windrow.

Rotary Hay Rakes

The rotary rake was developed in the late 1960's especially for use in high-yielding, European grass hay. The rotary rake concept is based on the idea of mechanizing the pitchfork; crop is swept up by the tines, then carried to the windrow where it is deposited by cam action. Rotary rakes have gained in popularity for their versatility to rake heavy silage hays as well as dry hay crops. The windrow produced is fluffy, allowing air to penetrate, improving crop dry-down. It is also said to feed balers and harvesters more uniformly. When raking alfalfa with a rotary rake, raking early and allowing the hay to dry in the windrow will minimize leaf losses from the raking action.

Wheel Hay Rakes

Ground driven wheel rakes quickly move hay along adjacent tine-finger wheels, lifting and moving dry crops to the windrow as it is passed along the wheels. While side-delivery models are commonly available, center-delivery wheel rakes (often called V-rakes) are the most popular configuration. The high-capacity, raking speed and windrow formation of the V-rakes make them ideal for round balers. Rakes are available from modest, 8 raking wheels to units with as many as 20 or even more wheels to match the capacity of the largest balers. Carted wheel rakes have a very basic design and are well suited for economy minded producers; large folding rakes feature independent wheel flotation and hydraulic adjustments to enhance performance and operator convenience.

Windrow Mergers and Inverters

Unlike traditional side delivery rakes and rotary rakes, windrow mergers pick up the windrow, depositing it onto a high-speed conveyor belt where it is moved above the ground, diminishing any risk of contaminants such as soil or stones from entering the hay. The cleanliness of the windrow merger makes it an essential tool when harvesting silage with a forage harvester.

Single windrow models may also be equipped with a special inversion chute to gently flip the crop, allowing damp material on the bottom of the windrow to dry without spoilage. The clean pickup and gentle inversion of hay minimizes field losses to provide the highest possible feed value. Windrow mergers are available in single and twin windrow pickup for small and medium sized producers as well as continuous swath pickup configurations for the highest capacity for large producers and custom harvesters.

Rotary Tedders

Making hay in humid and cool regions can be problematic because of the constant threat of showers and moisture from the morning dew. To help speed drying time, tedders have been developed to ted or fluff the hay crop either from a wide swath or narrow windrow. Clumps of wet crop are separated by the rotating tines as the machine is pulled forward; the crop is thrown up and rearward, distributed in a wide spread pattern to take advantage of the sun and air currents. While university research clearly indicates field losses from tedding, the potential improvement in drying rates may outweigh these losses when trying to dry hay ahead of expected poor weather. To minimize field losses, special care must be taken to only ted alfalfa while sufficient moisture is present to retain delicate leaves.

Combination Tedder-Rakes

Combination tedder-rakes are designed to provide the versatility to ted or rake crops in a single machine and are generally less costly than individual tools. Ideal for small farms and hobbyists, these machines are not suited for high acreage use. Although successful, their popularity has declined as farm size has increased.

Automatic Pickup Balers

Baling remains the most popular method of packaging hay, providing convenient packages for storing and feeding on the farm as well as affording the opportunity to market excess hay as a cash crop. Baling offers the lowest harvest power requirements per ton of dry feed. A single laborer can handle the task, though two often make more efficient use of both time and machines. Storing hay in bales also offers lowest per-ton-of-dry-matter storage cost. Space is used to better advantage, and in humid areas, bales can be dried in storage.

Small Square Balers

The traditional small square baler today is a mainstay of baling, particularly when the package size and shape are essential to farm operations. Small square bales permit maximum utilization of storage in traditional post and pin barns. Individual bales are easily handled without machinery when feeding small livestock herds and are the preferred package when feeding horses. Harvesting and storage is more labor intensive than round or large square bales, however efficiency is greatly improved with the addition of the bale thrower or automatic bale wagon.

Bale Throwers

In sharp contrast to the manual loading of small bales, throwers reduce labor and provide the complete mechanization of the hay handling system. Bales are tossed into wagons and hauled to a storage barn, placed on an elevator, conveyed and dropped into a mow randomly or stacked by hand to conserve space. This system greatly increases baled hay efficiency.

Bale throwers have four big advantages where small and medium-sized bales are preferred: (1) less man-power required, (2) faster hay making, (3) less weather risk, and (4) higher quality feed.

Bale throwers remove at least one man from the field, but commonly replace several laborers. Hydraulically driven throwers eject bales by spinning belts while kickers toss bales into the air as the wagon is pulled forward. Controls allow the throwing distance and bale trajectory to be adjusted from the tractor, ensuring wagons are filled to capacity.

Bale Conveyors

New, versatile, lightweight conveyors move small bales into the barn fast, allowing one man to do the job if randomly stacked. Basic conveyors are available in many lengths and most can be extended if necessary; more elaborate systems can carry bales across the barn to where they are needed, further reducing labor. Bale conveyor systems may also be used to take bales out of storage for winter feeding or shipment.

The capabilities of any bale-handling conveyor system and conveyor design are determined by angle of elevation, size, shape and consistency of bales. In general, shorter bales mean an elevator can't be as steep. Oddly shaped bales and bales with extremely low density may jam on the conveyor or fall off unexpectedly.

Automatic Bale Wagons

Automatic bale wagons mechanize bale handling for large and custom operators as well as for the smaller family farmer. They take the hands out of bale handling.

Automatic bale wagons are made two ways, self-propelled for large and custom operators, and pull-type for smaller operations with limited labor resources. All models pick up bales from the field, load, transport, and stack them in tight, weather-resistant stacks. Self-propelled models can be equipped with a specialized attachment to handle large square bales and quickly move even big square bales to storage.

Round Balers

Round balers continue to gain in popularity among many types of operations, especially the beef cow-calf producers.

However, dairymen are also moving toward large round bales, when feeding a total mixed ration with a vertical auger mixer.

Bale weights range from 850 to over 2,000 pounds, depending on the crop, baling conditions, and bale size. Round balers are available in various models that are capable of making bales 4 or 5 feet wide up to 6 feet in diameter. Individual bales are bound by either twine or net wrap.

Net wrap provides a significant improvement in handling and field productivity, binding bales more quickly than twine, as well as improving the weathering characteristics of the bale.

Some models provide pre-processing of the hay, slicing the bale for easier processing, while other models cut the hay to length as it is baled, improving bale density as well as palatability for livestock.

Round bales are typically stored outside and they resist weathering well; the rounded and thatched surface allows rain to shed. However, high storage losses can result from poor selection of storage location; round bales should be stored on dry ground and under cover whenever possible.

Large Square Balers

Large square balers provide the greatest packaging capacity and are designed for custom operators and growers who have large volumes of hay or straw to bale. The large square bale is a more economical package for long distance transportation.

Available in 3 feet x 3 feet and 3 feet x 4 feet x up to 8 feet in length, bale weight ranges between 1,000 and 1,500 pounds. Heavy-duty, double knotters tie each high-density bale, while New Holland's Bale Command™ system allows the operator to monitor all baler functions as well as the optional bale accumulator from inside the tractor cab. The optional accumulator carries and groups up to four bales for convenient pickup.

Plan for Better Bale Handling

Your father always said, "Work smarter, not harder." Today's haying tools shorten the crop's weather exposure between cutting and storage as well as save labor. While hay making will always remain challenging, modern mechanization takes much of the backache out of haymaking.

Hay Storage Facilities

Hay is perishable and feeding value can be lost by leaving it exposed to weather, especially in humid areas.

According to building specialists, a simple hay shed (often open on all four sides) could be justified in most cases outside the semiarid Southwest. A hay shed not over 24′ wide and at least 16′ to 20′ high at the eaves will be convenient and will permit the use of a bale conveyor or elevator. The approximate capacity of a 24′ wide hay shed, with a peaked roof 16′ high at the eaves, is two tons per running foot of length.

If you plan to build a shed for storing bales stacked by an automatic bale wagon, you should take these things into consideration:

(1) Make it accessible from both ends, particularly if it's a long barn.

(2) Make it high enough to allow the bale wagon to raise its load rack inside. (Seventeen feet is normally the minimum clearance needed, although some models can operate with less.)

(3) Ground should be solid to allow for good traction.

(4) Ground should be well drained and be reasonably level or have a slight dish in the middle.

Sickle Bar Mowers *Simplicity, high speeds, and greater widths keep the sickle bar mower popular. Forged steel cutterbar guards penetrate fine grasses and dense undergrowth with ease.*

Disc Mowers *Disc mowers cut by the slicing rather than shear cutting and mow more quickly than sickle bar mowers; they can handle fine grasses with wet or dead undergrowth and effortlessly cut through ant hills.*

Sickle Mower-Conditioners *Mower-conditioners cut and condition the crop simultaneously with rollers to hasten drying. Full lateral flotation permits the header to hug the ground over uneven terrain.*

Disc Mower-Conditioners *Disc mower-conditioners allow you to mow much more quickly than sickle models, approximately doubling productivity. Machines are fitted with either rolls or flails to condition crops for quick drying.*

Windrowers *Multi-purpose windrowers offer increased cutting capacity. Most can be equipped with either sickle, disc, and draper style heads. Hydrostatic drive provides improved control and infinite speed ranges to match crop conditions.*

Rakes *Side-delivery rakes are still widely used to make hay-crop windrows or turn hay for speedy field drying.*

Wheel Rakes *are available in configurations from 8 to 20 raking wheels, and quickly put large volumes of hay together for today's high capacity balers.*

Tedders *Tedders help speed drying of the hay crop. They are designed to ted or fluff the hay either from a swath or windrow, exposing the wet material to the sun while allowing air to penetrate and carry moisture away from the swath.*

Small Square Balers *Modern square balers are adapted for top capacity to satisfy a wide range of requirements of owners and users. Equipped with a bale thrower, labor requirements are significantly reduced.*

Large Round Balers *Large round balers are gaining in popularity among operators, especially beef cow-calf producers. However, some dairymen are also using large round bales. Round bales may be stored outside because of their tightly thatched, weather-resistant surface.*

Large Square Balers *Large square balers are designed for custom operators or hay growers who have large volumes of hay or straw. These are economical packages, ideal for long distance transportation, or feeding on large livestock and dairy operations.*

Automatic Bale Wagons *The automatic bale wagon mechanized bale handling for the large custom operator as well as for the smaller family farmer. Both self-propelled and pull-type models pick up bales from the field, load, transport, and stack bales in a tight stack.*

CHAPTER 14

Mapping Out Haying Systems

In our modern age we are certainly exposed to a wide variety of systems. Most frequently, farmers think of electronics, hydraulics, or computers when the word system is mentioned. However, the term system also applies to the group of machines selected to provide the best efficiency for a series of operations.

A "haymaking system" would be the group of machines that are planned to do all the operations required to make hay, including cutting, gathering, packaging, stacking and retrieving, and might also be extended to feeding the crop. These individual steps in the system must be matched, or man and machines will sit idle while waiting on another machine or operator, resulting in inefficiency and higher production costs.

Correctly choosing a hay-making system is not a difficult task, but rather one that requires a thorough analysis. The producer must determine what it is they wish to accomplish, examine the alternative solutions available, consider their physical constraints and

Correctly choosing a haymaking system is not a difficult task, but rather one that requires a thorough analysis. The producer must determine what it is they wish to accomplish, examine the alternative solutions available, consider their physical constraints and determine their financial position when making the decision.

determine their financial position when making the decision. The options available to producers selecting machines for a hay system have expanded dramatically since 1970, probably more so than in the previous 200 years.

Modern machines enable the complete mechanization of hay harvesting from field to feeding. It is now possible to assemble a good hay harvesting system which is fast, reduces drudgery, saves labor, maximizes nutrients, increases profits, and is efficiently managed. However, it is imperative to keep in mind that no one set of machines or practices can suit all hay-making requirements, due to production type and climate variation.

The best system for a specific haying operation is dependent upon climate, soil conditions, type of farming, amount of hay harvested, and whether the hay will be fed on the farm or sold. To assist an individual in selecting the proper equipment for an efficient system, this chapter may be used as a guide to understanding the relationship between the hay-making system and the requirement of the farm operation.

Establishing System Requirements

The hay-making system must be sized adequately to meet the needs of the grower's operations. To work efficiently, first consider the production volume before establishing the equipment for making up the hay-making system.

For livestock feeding operations, this is calculated as the number of animals in the herd and the amount of hay they will consume each day, extrapolated across a full year and represented as "dry matter tons/year." This is determined by multiplying the number of animals, the number of pounds of dry matter each will consume per day, 365 days per year, and then dividing by 2,000.

For example, a dairy milking 40 cows, feeding 50 pounds of dry matter per cow each day would require 2,000 pounds per day or 1 ton of dry matter. To feed this ration, the farm would need to harvest 365 tons of hay each year (2,000 lbs-day x 365 days / 2,000 lbs-ton = 365 tons-year). Since the ration will vary by the animals' ages and status, it is important to calculate this independently for various groups of animals to determine production requirements.

Figures 14-1 and 14-2 were prepared as a quick reference to find the annual tonnage required for an operation. The production requirements will vary by farm type, geography, and crops grown, so when determining the requirements for a specific operation, it is recommended to contact the local cooperative extension agency, or an animal nutritionist for assistance.

Acreage Requirements

Once livestock producers have established the annual tonnage required, they must next consider the acreage necessary to meet this production. This is calculated simply by multiplying the tons produced per acre and the total acreage harvested to find the tons harvested (tons per acre x acreage = tons harvested). Since the number of harvests and yield will vary by season, geography, and crop type, calculate each harvest individually, then combine to find the total annual production.

In the previous example we found the 40-cow dairy requires 1 ton of dry matter per day or 365 tons per year. If the average yield was 3.5 tons per acre, the producer would need to harvest 104 acres to meet the consumption of his animals (tons ÷ tons-acre = acreage required).

Another way for producers to evaluate production is to consider their capacity of an established acreage. If the example dairy was harvesting 40 acres of choice alfalfa four times annually, the actual production would total 160 acres with a production capacity of 560 tons. This capacity would provide an additional 195 tons available for other livestock or hay, which can be sold to generate revenue (acreage x yield = tons of production).

Selecting Equipment for a System

Since several machines are required to form a complete system, the machinery selections must complement each other in terms of width and capacity, or the resulting overall efficiency is poor. Poor efficiency or mismatched components can result in lowering the quality of the hay harvested and increasing operational cost. Rarely are complete new systems purchased, so the grower must continually update his system with new, more efficient harvesting equipment that is compatible with existing machines, while also considering future needs.

To assist producers in choosing complementary machinery well-suited to

FIGURE 14-1

Annual tons of dry matter production

Lbs. of DM / Day

Num. of Animals	20	30	40	50	60	70	80	90	100
25	91.3	136.9	182.5	228.1	273.8	319.4	365.0	410.6	456.3
40	146.0	219.0	292.0	365.0	438.0	511.0	584.0	657.0	730.0
50	182.5	273.8	365.0	456.3	547.5	638.8	730.0	821.3	912.5
75	273.8	410.6	547.5	684.4	821.3	958.1	1095.0	1231.9	1368.8
80	292.0	438.0	584.0	730.0	876.0	1022.0	1168.0	1314.0	1460.0
100	365.0	547.5	730.0	912.5	1095.0	1277.5	1460.0	1642.5	1825.0
125	456.3	684.4	912.5	1140.6	1368.8	1596.9	1825.0	2053.1	2281.3
150	547.5	821.3	1095.0	1368.8	1642.5	1916.3	2190.0	2463.8	2737.5
175	638.8	958.1	1277.5	1596.9	1916.3	2235.6	2555.0	2874.4	3193.8
200	730.0	1095.0	1460.0	1825.0	2190.0	2555.0	2920.0	3285.0	3650.0
225	821.3	1231.9	1642.5	2053.1	2463.8	2874.4	3285.0	3695.6	4106.3
250	912.5	1368.8	1825.0	2281.3	2737.5	3193.8	3650.0	4106.3	4562.5
500	1825.0	2737.5	3650.0	4562.5	5475.0	6387.5	7300.0	8212.5	9125.0
750	2737.5	4106.3	5475.0	6843.8	8212.5	9581.3	10950.0	12318.8	13687.5
1000	3650.0	5475.0	7300.0	9125.0	10950.0	12775.0	14600.0	16425.0	18250.0
1500	5475.0	8212.5	10950.0	13687.5	16425.0	19162.5	21900.0	24637.5	27375.0

FIGURE 14-2
Tons of Production

Hay Acreage

Tons/Acre	25	50	75	100	125	150	175	200	225	250
1.5	38	75	113	150	188	225	263	300	338	375
2.0	50	100	150	200	250	300	350	400	450	500
2.5	63	125	188	250	313	375	438	500	563	625
3.0	75	150	225	300	375	450	525	600	675	750
3.5	88	175	263	350	438	525	613	700	788	875
4.0	100	200	300	400	500	600	700	800	900	1000
4.5	113	225	338	450	563	675	788	900	1013	1125
5.0	125	250	375	500	625	750	875	1000	1125	1250
5.5	138	275	413	550	688	825	963	1100	1238	1375
6.0	150	300	450	600	750	900	1050	1200	1350	1500
6.5	163	325	488	650	813	975	1138	1300	1463	1625
7.0	175	350	525	700	875	1050	1225	1400	1575	1750
7.5	188	375	563	750	938	1125	1313	1500	1688	1875
8.0	200	400	600	800	1000	1200	1400	1600	1800	2000
8.5	213	425	638	850	1063	1275	1488	1700	1913	2125

Tons of Production

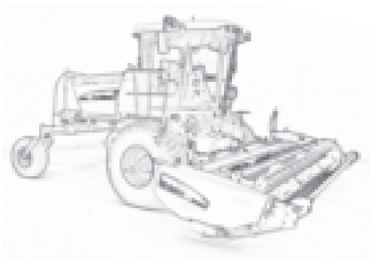
working together, capacity and labor requirements for representative equipment are shown in Figures 14-3, 14-4 14-5, and 14-6. These figures were calculated on the yield assumption of 1.2 tons per acre production based on USDA data for non-irrigated lands, a one-mile haul distance, and a field capacity assuming an 80% efficiency. This efficiency rating accounts for time necessary to lubricate, fuel, make minor repairs, and lost time while turning in the field. When considering production on irrigated lands, assuming a conversion factor of 2.5 may be applied to calculate a yield of 3.0 tons per acre.

These figures can be expanded to different cutting widths by multiplying the capacity and labor figures by the appropriate correction factors. Therefore, even though only a few specific machines are shown, these charts give the producer a base from which to estimate capacity and labor requirements for other machines that might match the overall system.

For example, if you wished to use an 18' SP disc windrower, the capacity and labor requirement can be calculated from the data for the 15'5" unit shown by multiplying by the ratio of the two cutting widths – (18÷15.4) x 19 = 22.04 tons/hour, and (15.4÷18) x .05 = .042 man-hours/ton.

Another approach to measuring productivity is often reflected as the total number of acres it is possible to work with a machine in one hour. If a grower wishes to evaluate the total time required to mow a given acreage, it is possible to quickly divide the total acreage by the productivity measured by acres per hour. To calculate productivity in acres per hour, multiply speed (mph) and

(continued on page 126)



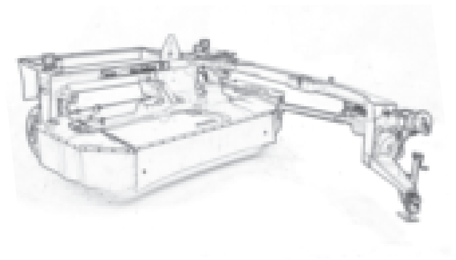
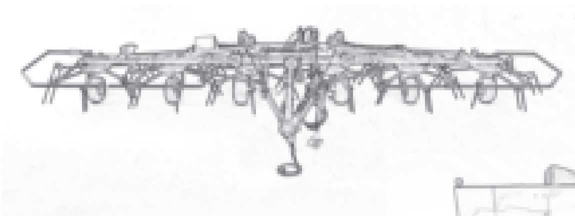


FIGURE 14-3
CUTTING MACHINES

	Cutting Width	Speed *(mph)*	Efficiency	Capacity Acres/ Hour	Capacity Tons/ Hour	Labor Man hours/Ton
1) MOWER						
Sickle	7'	4	80%	2.5	3	0.33
	9'	6	80%	4.9	6	0.17
Disc	5' 6"	8	85%	4.1	5	0.20
	6' 8"	8	85%	5.1	6	0.16
	7' 10"	8	85%	6.0	7	0.14
	9' 2"	8	85%	7.1	9	0.12
	10' 4"	8	85%	8.1	10	0.10
2) MOWER CONDITIONER						
Sickle	7'	5	80%	3.2	4	0.26
	8' 6"	5	80%	3.9	5	0.21
	9' 2"	5	80%	4.2	5	0.20
Disc	9' 2"	8	85%	7.1	9	0.12
	10' 4"	8	85%	8.1	10	0.10
	13'	8	85%	10.3	12	0.08
	15' 7"	6	85%	7.3	9	0.11
3) SELF PROPELLED WINDROWER						
Sickle	12' 3"	6	82%	7.0	8	0.12
	14' 3"	6	82%	8.2	10	0.10
	16' 3"	6	82%	9.4	11	0.09
	18' 3"	6	82%	10.6	13	0.08
Disc	13'	10	87%	13.2	16	0.06
	15' 5"	10	87%	15.7	19	0.05
	18'	10	87%	18.5	22	0.04



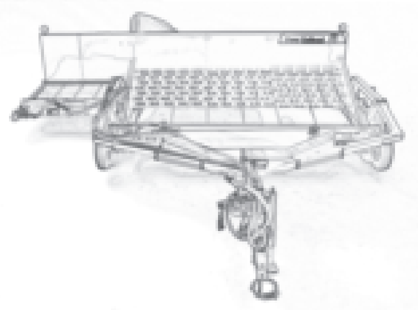
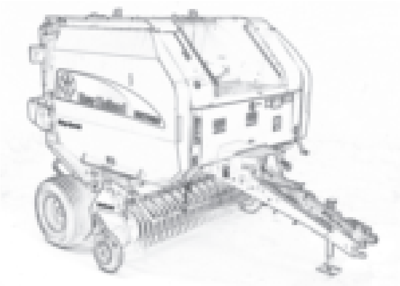
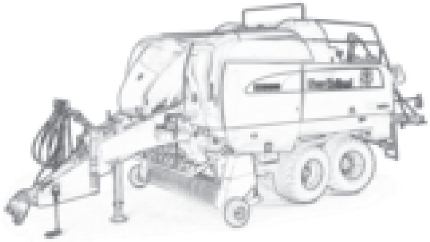


FIGURE 14-4

FLUFFING & GATHERING MACHINES

	Width	Speed (mph)	Acres/Hour	Tons /Hour	Man-hrs. / Ton
1) ROLABAR® RAKE					
	8' 6''	4	3.3	3.96	0.25
	9' 6''	4	3.7	4.42	0.23
2) WHEEL RAKE					
	16' 4''	8	12.7	15.20	0.07
	17' 5''	8	13.5	16.21	0.06
	19'	8	14.7	17.69	0.06
	20' 4''	8	15.8	18.93	0.05
	21' 8''	8	16.8	20.17	0.05
	25''	8	19.4	23.27	0.04
	28' 6''	8	22.1	26.53	0.04
	30' 10''	8	23.9	28.70	0.03
	33' 5''	8	25.9	31.11	0.03
	36'	8	27.9	33.51	0.03
3) WINDROW MERGER/INVERTER					
Inverting Windrows	9'	10	11.2	13.44	0.07
	12'	10	14.1	16.92	0.06
Combining two Windrows	9'	10	22.3	26.76	0.04
	12'	10	28.1	33.72	0.03
4) ROTARY TEDDER					
4 - rotor	16' 6''	4	6.4	7.68	0.13
6 - rotor	25' 7''	4	9.9	11.91	0.08





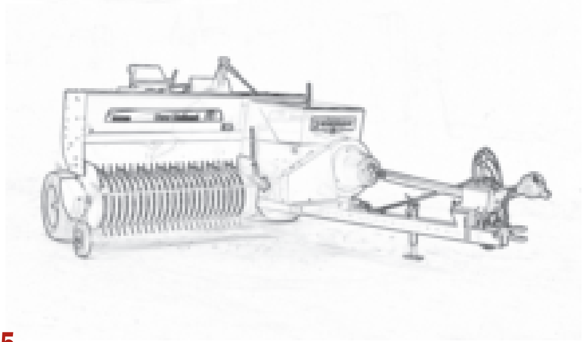


FIGURE 14-5

PACKAGING MACHINES

	Bale Size	cu/ft	Bale Weight	Tons/Hr.	Man hrs / Ton
1) SMALL SQUARE BALER					
	14"x18"x36" (79 spm)	5.3	50 - 55 lbs	3.41	0.29
	14"x18"x36" (93 spm)	5.3	65 - 70 lbs	4.86	0.21
Hayliner®	14"x18"x41" (93 spm)	6.0	85 - 90 lbs	6.30	0.16
	16"x18"x41" (93 spm)	6.8	95 - 105 lbs	7.20	0.14
2) LARGE SQUARE BALER					
	3'x3'x7.5'	58.1	1000 - 1150 lbs	30.00	0.03
	3'x4' x7.5'	87.2	1500 - 1650 lbs	45.00	0.02
3) ROUND BALER					
	4'x4'	48.7	500 - 550 lbs	11.81	0.08
	4'x5'	76.1	850 - 900 lbs	21.00	0.05
	5'x5'	100.6	1150 -1250 lbs	27.00	0.04
	4'x6'	102.4	1200 - 1300 lbs	28.13	0.04
	5'x6'	135.4	1650-1750 lbs	35.70	0.03

FIGURE 14-6

RETRIEVE AND STACK

	Bale Size	Bales/ Load	Bale Weight	Lbs/ Load	Tons/ Hour	Man-Hr/ Ton
1) MANUAL						
Truck - 3 laborers		-		-	2.7	1.11
Trailed Wagon		-		-	-	0.60
2) AUTOMATIC BALE WAGON						
Pull-type Wagon	14"x18"x36" *(79 spm)*	104	55-60 lbs	5980	5.98	0.17
	14"x18"x 38" *(93 spm)*	104	60-75 lbs	7280	7.28	0.14
	16"x 18"x41" *(93 spm)*	83	85-90 lbs	7263	7.26	0.14
Self-Propelled Wagon	14" x 18" x 38" *(93 spm)*	161	85-90 lbs	14088	14.09	0.07
	16"x18"x41" *(93 spm)*	161	95-105 lbs	16100	16.10	0.06
	3' x 3'	15	1000-1150 lbs	16125	16.13	0.06
	3' x 4'	10	1500-1650 lbs	15750	15.75	0.06
3) Round Bales						
Rear Bale Spear					2.5	0.40
Rear Bale Spear & Front Loader					5	0.20
Towed bale Carrier					11.5	0.09

width (ft) by a factor already adjusted for efficiency found in Figure 14-7. For example, the productivity of a 13´ disc mower-conditioner operated at 8 mph with 85% efficiency can be estimated at 11 acres per hour (13´ x 8 mph x .103 = 10.7 acres/hour).

FIGURE 14-7

Efficiency	Factor
75%	0.091
80%	0.097
85%	0.103
90%	0.109
95%	0.115
100%	0.121

Evaluating Productivity

The example, a 40 cow dairy farm, is considering the purchase of a 9´ 2″ mower-conditioner and is comparing sickle and disc models. They expect to mow 40 acres in an afternoon. By dividing this acreage by the productivity of each model found in figure 14-3 they find that a sickle model may not be a practical solution (40 acres ÷ 4.2 acres per hour = 9.5 hours). The disc model provides faster cutting than the sickle model, reducing the time required by nearly 4 hours (40 acres ÷ 7.1 acres per hour = 5.6 hours).

Selecting Supporting Implements

Tedders, rakes and other supporting implements must be sized appropriately to the mower or mower-conditioner in order to work efficiently. These ma-

FIGURE 14-8

Machine	Acrage		Acres / Hour		Time (Hrs.)
Sickle Mower Conditioner 9' 2'' (5 mph)	40	÷	4.20	=	9.52
Disc Mower Conditioner 9' 2'' (8 mph)	40	÷	7.14	=	5.60
					3.92

chines will follow the mower or mower-conditioner, and consideration must be given to both the mown and swath width. In the case of the hay rake or merger, it must also produce a windrow suitable for harvesting by the baler or forage harvester which will follow.

When considering requirements of supporting machines, you must first consider the number of windrows you want to work simultaneously. When working with single windrows, a rake or tedder should be sized to closely match the cutting width of the mower. This ensures that individual windrows are uniformly spread, and that partial windrows are not inadvertently raked as a consequence of an unnecessarily large rake.

To establish the size requirements when working with multiple windrows, you must consider the width of cut as well as the windrow width. To calculate the required width to manipulate two windrows simultaneously, simply add the width of cut to the windrow width. Therefore, to ted after a 10´4˝ mower-conditioner forming 5´6˝ windrow, a minimum working width of 15´10˝ working width is necessary (10´4˝ + 5´6˝ = 15´10˝). In this case a 4 rotor model with a working width of 16' 6" is ideal. Figure 14-9 may be used as a guide when determining the widths required for supporting machines.

The Modern Hay Baler

The modern hay baler is available in many configurations, from the traditional small square baler to modern high-capacity large square and round balers. When selecting a baler for the hay-making system it is crucial to evaluate production requirements, available labor, bale handling, bale storage, and machines already selected for the system. Only by examining these elements will you ensure that a baler is well suited to the operation and complementary to the haymaking system.

The first consideration should be baler capacity, to ensure that the hay is baled at the proper time and moisture to produce the highest quality forage. If the baler lacks sufficient capacity to bale all the hay in a timely fashion, there is greater risk of spoilage from rains or sun bleaching. Required capacity is calculated by multiplying the acreage and yield, then dividing by the time available to bale the acreage. For example, 40 acres of hay yielding 3.5 tons per acre will produce 140 tons; to bale the hay in 6 hours, a capacity of 23.3 tons per hour (40 acres x 3.5 tons per acre ÷ 6 hours = 23.3 tons per hour) is required. Referencing Figure 14-5, both 4´x 6˝ and 5´x 5˝ round balers have a capacity well suited to this production requirement.

With this simple calculation it is possible to compare the effects of

FIGURE 14-9

1) Combining Two Windrows - Mower Cut and Windrow Widths at 4" Mower Overlap											
		3'	4'	5'	4'	6' 6"	5'	8'	6' 6"	8' 6"	9'
Sickle	7'	-	-	-	-	13.17	-	-	-	-	-
	9'	-	-	-	-	-	-	-	-	17.17	-
Disc	5' 6"	-	9.17	10.17	-	-	-	-	-	-	-
	6' 8"	-	-	-	10.34	12.84	-	-	-	-	-
	7' 10"	-	-	-	-	-	12.50	15.50	-	-	-
	9' 2"	-	-	-	-	-	-	-	-	-	-
	10' 4"	-	-	-	-	-	-	-	16.50	-	19.00

2) Combining Two Windrows - Mower Conditioner Cut and Windrow Width at 4" Mower Overlap														
		3'	3'2"	4'	4'5"	4'10"	5'2"	5'7"	6'	6'5"	6'10"	7'2"	7'7"	8'
Sickle	7'	-	9.87	10.67	11.07	11.47	11.87	12.27	12.67	13.07	-	-	-	-
	9'2"	-	12.04	12.84	13.24	13.64	14.04	14.44	14.84	15.24	15.64	16.04	16.44	16.84
	12'3"	-	15.12	15.92	16.32	16.72	17.12	17.52	17.92	18.32	18.72	19.12	19.52	19.92
	14'3"	-	17.12	17.92	18.32	18.72	19.12	19.52	19.92	20.32	20.72	21.12	21.52	21.92
	16'3"	-	19.12	19.92	20.32	20.72	21.12	21.52	21.92	22.32	22.72	23.12	23.52	23.92
	18'3"	-	21.12	21.92	22.32	22.72	23.12	23.52	23.92	24.32	24.72	25.12	25.52	25.92
Disc	9'2"	11.84	12.04	12.84	13.24	13.64	14.04	14.44	14.84	-	-	-	-	-
	10'4"	13.00	13.20	14.00	14.40	14.80	15.20	15.60	16.00	16.40	16.80	-	-	-
	13'	15.67	15.87	16.67	17.07	17.47	17.87	18.27	18.67	19.07	19.47	19.87	20.27	20.67
	15'7"	18.25	18.45	19.25	19.65	20.05	20.45	20.85	21.25	21.65	22.05	22.45	22.85	23.25

3)Combining Two Windrows - Self Propelled Windrower Cut and Windrow Widths at 4" Mower Overlap														
		3'	3'2"	4'	4'5"	4'10"	5'2"	5'7"	6'	6'5"	6'10"	7'2"	7'7"	8'
Sickle	12'3"	14.92	15.12	15.92	16.32	16.72	17.12	17.52	17.92	18.32	18.72	19.12	19.52	19.92
	14'3"	16.92	17.12	17.92	18.32	18.72	19.12	19.52	19.92	20.32	20.72	21.12	21.52	21.92
	16'3"	18.92	19.12	19.92	20.32	20.72	21.12	21.52	21.92	22.32	22.72	23.12	23.52	23.92
	18'3"	20.92	21.12	21.92	22.32	22.72	23.12	23.52	23.92	24.32	24.72	25.12	25.52	25.92
Disc	13'	15.67	15.87	16.67	17.07	17.47	17.87	18.27	18.67	19.07	19.47	19.87	20.27	20.67
	15'5"	18.09	18.29	19.09	19.49	19.89	20.29	20.69	21.09	21.49	21.89	22.29	22.69	23.09
	18'	20.67	20.87	21.67	22.07	22.47	22.87	23.27	23.67	24.07	24.47	24.87	25.27	25.67

alternative balers on the systems. Examining again the example of the 40-cow dairy, it is evident from Figure 14-10 that replacing a small square baler with a round baler can reduce the man-hours per ton required harvest and store by nearly 45%. This significant reduction in manpower will unquestionably have a direct impact on farm profitability.

However, it is crucial to understand that other system components such as the rake must change to accommodate the additional capacity of the round baler. Incorporating a larger, V-type wheel rake exploits the full capacity of the round baler, while an additional labor reduction of nearly 10% is achieved.

FIGURE 14-10

Machine		Labor
Discbine® Mower-Conditioner (9'2")		0.12
Rolabar® Rake (9'6'')	+	0.23
Tedder (16'6'')	+	0.04
14'x18' Small Square Baler	+	0.21
Trailed Wagon	+	0.60
Total Man-hours per Ton		**1.19**
Annual Production *(tons)*		560
Total Man-hours per Ton	x	1.19
Labor Required (hours)		**666.50**
Annual Production *(tons)*		560
Average bale weight *(tons)*	x	0.03
Number of bales per year		**17231**

Machine		Labor
Discbine® Mower-Conditioner (9'2")		0.12
18' V-type wheel rake	+	0.06
Tedder (16'6'')	+	0.04
4'x4' Round Baler (500 lb bale)	+	0.08
Rear Bale Spear & Front Loader	+	0.20
Total Man-hours per Ton		**0.50**
Annual Production *(tons)*		560
Total Man-hours per Ton	x	0.50
Labor Required (hours)		**277.59**
Annual Production *(tons)*		560
Average bale weight *(tons)*	x	0.25
Number of bales per		**2240**

Balers That Pre-cut

Large square and round balers equipped with knives pre-process the hay by cutting the material down to a uniform, consistent length as it is baled. Pre-cutting increases bale density 10% to 15%, reducing levels of trapped oxygen inside the bale and improving fermentation. Pre-cut bales are more easily processed by feed mixers, saving time and providing superior ration consistency to long-stem bales processed by the mixer.

Bale Storage

Often more consideration is given to the act of baling hay than why baling is done in the first place. Frequently, in a rush to beat the weather, we forget that hay is cured and baled so that it may be kept for some period of time and fed or sold when grazing and other feeds are not available. Bale storage and freight are the final keys to the hay-making system.

The traditional "Hip-Roof" or "Post and Pin" barn may not be ideal storage structures for high-capacity large square and round bales, yet they remain the romantic hay storage structures. Regrettably, improper bale storage contributes to unnecessary dry matter losses, sun bleaching, and molding. Whenever possible, bales should be stored on well drained pads under the cover of a roof or stack-tarp to prevent weathering and bale deterioration.

Losses from improper storage can range from 5% to 20% in the first nine months and as high as 15% to 50% for bales improperly stored for 12 to 18 months. The effect of improper bale storage can quickly translate into a poor return on investment.

Consider our example 40-cow dairy evaluating a round baler in place of the small square baler to improve labor efficiency; without providing adequate storage for the estimated 2,240 round bales produced, weathering loss of only 10% would result in an estimated 60 tons gone to waste. Valued at $25 per bale, the 224 lost bales account for $5,600 in lost farm revenue. Bale storage structures can quickly pay for themselves by reducing losses from improper storage.

When hay is marketed and shipped locally, regionally, and internationally, producers must consider both the bale dimensions and weight that will safely fit on a truck or into a container. As legislative pressures increase on producers, knowing the weight of individual bales in the field can maximize tonnage per load when bales are ferried by truck. New technologies can provide accurate bale weights, moisture levels, preservative application rates, and relative feed value measurements; radio frequency tagging of the bales provides quick sorting by weight and quality so the highest quality bales can be segregated and marketed as premium hay. When combined with GPS technology, these systems also have the potential for yield monitoring, allowing producers to reduce inputs while gaining quality.

Summary

This chapter has given some insight into the selection of a machinery system which can be matched to a particular farm. Selection of the individual components that make up this system is an important task. The system chosen must have the capacity to minimize losses through harvest timeliness, while maintaining an acceptable cost level.

Selecting the proper equipment to match the management needs of the system is equally important to obtain good overall field performance. We suggest you seek assistance in selecting equipment through the local New Holland farm equipment dealer, university extension personnel, or other farmers in the area. Often university personnel have access to machinery management computer programs that will be helpful in analyzing the total system, including costs and labor efficiency.

Packaging

CHAPTER 15

Large Round Bales for Hay and Silage

Large round bales for hay and silage can decrease labor markedly and result in animal performance and carrying capacity per acre similar to other hay and silage systems.

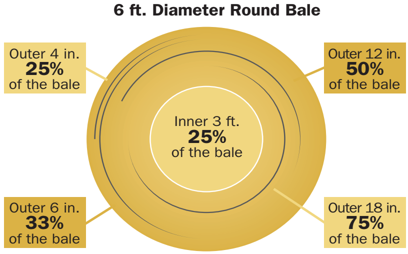
Large round bales for hay and silage can decrease labor markedly and result in animal performance and carrying capacity per acre similar to other hay and silage systems. However, losses can be severe if bales are not properly made, stored, and fed. Thus, in order to make these systems pay off, you need to pay attention to detail in every step of the operation. In this chapter, we'll review tactics for making and storing large round bales as hay or silage. Feeding systems for these bales will be covered in the appropriate livestock chapters.

Bales Described

Large round bales are essentially cylinders, and depending on the baler, can be between 4 – 6 ft (1.2 – 1.8 m) in width and 3 – 6 ft (0.9 – 1.8 m) in diameter. The density of hay within the bale varies with over 30% of the bale's weight in the outer 6 inches and 25% in the next 6-inch layer. Combined, there is more than 50% of the bale's weight in the outer 12 inches of the bale. So, spoilage on the outside of the bale will destroy proportionally more material compared to the center. Figure 15-1 displays the approximate proportion of material within a large round bale while Figure 15-2 shows the amount of potential dry matter loss in the outer layers of bales with differing diameters. As the bale diameter becomes larger, the proportion of dry matter spoilage loss during storage becomes smaller (Figure 15-3).

FIGURE 15-1

Approximate proportions of hay within the structure of a 6 ft diameter bale.



Source: Haag, E. Baling Strategy Cuts Losses. Angus Journal October 2007, pg 282-285.

There are several management steps that will minimize losses during baling and storage of large round bales:

1. Preparing the Windrow:

A. Windrows should be uniform in width and depth so that material feeding into the bale chamber is fairly constant, producing a more uniformly dense bale.

B. A heavy windrow improves feeding of material into the baler, reduces field losses, puts less wear-and-tear on the baler and tractor, and permits you to make more bales per hour. In light crops, rake or merge two or more windrows together to get the benefits of a heavy windrow.

C. If you cut hay with a mower-conditioner, rake in the same direction as you mow. Do not allow the hay to pile up or drag. Raking into a windrow just prior to the point of excessive leaf shatter will reduce field losses.

2. Moisture at Baling:

A. Moisture at baling is critical. The best rule to follow is – make round bales at the same moisture content as you are accustomed to for conventional rectangular bales.

3. Using Preservatives:

A. Hay can be baled safely as large round bales at moistures above 20%, if a preservative or supplemental drying is used. But without special attention, baling at higher moistures can result in major losses since the cores of large round bales tend to be less dense than the exterior portion. This difference in density allows more oxygen penetration into the bale interior and promotes mold and yeast growth in high moisture situations.

4. Baling Density:

A. Bale densities will vary with the kind of hay (grass or legume). Density should be uniform throughout the bale to maintain bale shape after ejection and limit external weathering. Further, storage and feeding practices may determine how dense a bale should be rolled.

B. Variable chamber balers produce bales with more uniform density throughout regardless of the bale size because the belting system keeps a constant pressure on the hay during bale formation. Fixed chamber balers will produce bales with softer (i.e., less dense) cores than those produced

FIGURE 15-2

Potential % of dry matter losses in outer layers of large round bales with increasing diameters

Bale Diameter	Outer Layer Depth			
	2 in	4 in	6 in	8 in
4 ft	16%	31%	44%	56%
5 ft	13%	25%	36%	46%
6 ft	11%	21%	31%	40%
7 ft	9%	18%	27%	34%
8 ft	8%	16%	23%	31%

Source: Hundtoft. E.B. 1965 Cornell Univ. Agric. Engineering Ext. Bull. 364. Ithaca, NY.

in variable-chamber balers because the hay rolls loosely in the bale chamber as it fills and maximum bale density is not reached until the bale reaches its full size within the chamber.

5. Bale Wrapping:

A. There are three types of bale wrappings for large round bales: twine, net wrap, and plastic wrap.

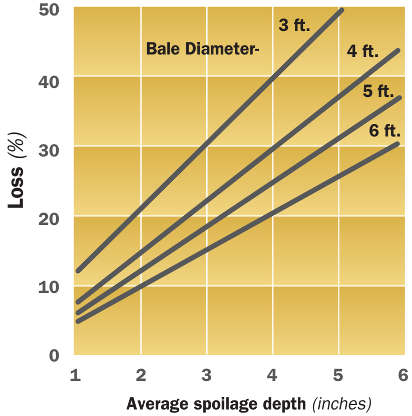
Twine, either sisal or poly, is the least costly type of wrap to purchase, but it takes more spins (i.e., normally 8) to produce the bale with twine than with the net or plastic wrap (i.e., normally 2 spins). This extra stop time to wrap the bale with twine often negates the cost savings.

Net wrap is a woven material designed to shed water away from the bale surface while promoting greater airflow. This material normally requires only two spins to wrap a bale. Storage losses are similar to those with twine when the exterior bale density is the same. However, net wrap may re duce leaf loss from the chamber during bale formation compared to twine wrapping.

Plastic wrap is a solid plastic barrier that sheds water completely and provides ultraviolet light protection for the bale. Dry matter losses during storage are up to five times less with plastic wrap compared to unwrapped bales on the ground. However, plastic wrap has a much higher purchase price.

FIGURE 15-3

Estimated dry matter losses in large round bales when the outside layers become spoiled.



Source: Buckmaster, D.R. Round Hay Bale Storage. PSU Extension Fact Sheet I-112

Storing Large Round Bales

Storage of large round bales needs to balance input cost with the cost of lost DM (Dry Matter). Leaving bales outside on the ground has the lowest input cost, but the DM losses are large and will accelerate rapidly with time. Numerous universities have studied DM losses in large round bales with various forms of storage. One example of this research is presented in Figure 15-4 and is fairly representative of expected losses across most of the country. More humid locations would have greater losses, especially during warm weather.

If we combine the possible DM losses in different types of storage with the market price of hay (see Figure 15-5), it is easy to see that covering and elevating hay bales provides a significant

FIGURE 15-4

Percent dry matter loss of round hay bales under different storage conditions

Storage Method	Storage Duration Up to 9 months*	12 to 18 months
Outside - Exposed		
Ground	5 - 20%	15 - 50%
Elevated	3 - 15%	12 - 35%
Outside - Covered		
Ground	5 - 10%	10 - 15%
Elevated	2 - 4 %	5 - 10%
Storage structure		
Under roof	2 - 5%	3 - 10%
Enclosed in barn	2%	2 -5%

* If used before warm weather. Source: Hutnke, R. L. Round Bale Hay Storage. Oklahoma Cooperative Extension Fact Sheet BAE-1716

payback on investment. Most economic analyses suggest that a rock base pad with a reusable waterproof tarp/plastic covering is the least costly form of storing large round bales regardless of the market price of the hay being stored.

Plastic Covers

There are a variety of plastic covers for hay bales on the market:

Plastic Tarps have become the popular choice in many areas for covering large round hay bales. The tarps are reusable and versatile compared to other types of covers. However, wind damage is a potential problem requiring repair and maintenance. Reinforced plastic tarps are more durable and require less maintenance than plastic sheeting. Remember that plastic materials will trap moisture and could cause spoilage losses in more humid areas.

Bonnets or Caps have been a popular alternative in the past. They offer similar advantages and disadvantages as tarps. However, bonnets and caps are not as versatile because they may be designed for individual or small groups of bales.

Sleeves are also gaining favor in some areas, and in dry areas of the country can be nearly as effective as barn storage in preserving hay quality. But problems of fitting the sleeves over bales have been a concern of some farmers.

Bale Bags are a third alternative for field-covered and protected individual bales, and while they provide the most complete protection, they appear to be less widely used than either tarps, caps or sleeves.

FIGURE 15-5

Economic cost of storage losses in hay

Storage Loss *(% of bale)*

Market Price of Hay $/ton @ 16% Moisture	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
$80	$4	$8	$12	$16	$20	$24	$28	$32	$36	$40
$100	$5	$10	$15	$20	$25	$30	$35	$40	$45	$50
$120	$6	$12	$18	$24	$30	$36	$42	$48	$54	$60
$140	$7	$14	$21	$28	$35	$42	$49	$56	$63	$70
$160	$8	$16	$24	$32	$40	$48	$56	$64	$72	$80
$180	$9	$18	$27	$36	$45	$54	$63	$72	$81	$90
$200	$10	$20	$30	$40	$50	$60	$70	$80	$90	$100
$220	$11	$22	$33	$44	$55	$66	$77	$88	$99	$110

Adapted from: Holmes. 2004. Dry Round Hay Bale Storage Costs. Focus on Forage Fact Sheet Vol 6: Issue 5

Bale Silage

Bale silage or baleage has gained enormous popularity in the humid (north central and northeast) and wet (south central and southeast) regions of the U.S. In areas where hay dry down is a challenge, the option to place wet hay in a sealed bag provides more flexibility for hay crop storage.

Baleage, of course, is not new. The method follows the same practice as making dry hay bales except that the hay crop is baled at higher moisture (35% to 55% normally), and then wrapped in a tight-sealing plastic film or packed in a tight-fitting plastic tube. Farmers in many countries have been making it for years with generally satisfactory results. Making baleage has become relatively easy with the advent of new lines of machinery to wrap or pack the bales. Any type of bale (large round, large square or small square) can be made into baleage. What used to be a two- to three- person operation is now a one-person operation. The main issue remains getting the bale wrapped and sealed as quickly as possible after baling to reduce oxygen exposure which leads to DM and nutrient losses. As with making high-quality hay, the farmer has to pay attention to details in order to make high-quality baleage.

The following is a comparison of the advantages and disadvantages of making baleage:

Advantages:

- Lower capital investment compared to conventional chopped silage production.
- Roughly 1/3 lower fuel consumption than conventional chopped silage production.
- Feed quality can be improved due to retention of leaves, especially in legume crops.
- Harvest and storage losses can be lower than dry hay baling due to leaf retention and protection against weather during storage.
- Individually wrapped silage bales are more portable than chopped silage.
- Small amounts of forage that can be ensiled, stored, and moved with little loss.
- Baleage feeding does not require specialized machinery.

Disadvantages:

- Long (unchopped) forage crops are harder to ensile than chopped forage because there are less fermentable carbohydrates available.
- Balers and handling equipment must be strong enough to handle the heavier wilted (50% to 60% moisture) forage.
- Bale weights are greater, requiring large tractors and handling equipment.
- Plastic wrap material can tear or puncture, leading to spoilage.
- Maintenance and repair of plastic is necessary.
- Plastic is not reusable and must be properly disposed of.

Proper Sealing of the Bale Is the Key

The most important part of making high-quality baleage is the complete sealing of the bale as soon as possible after baling. The objective is to cut off exposure to oxygen as quickly as possible, changing the fermentation process from aerobic to anaerobic, encouraging the formation of desirable acids, keeping the bale temperature low, and reducing spoilage. Since the forage is not chopped, there is less carbohydrate (i.e., sugars) available for fermentation. As a result, there are smaller amounts of fermentation acids to prevent spoilage and pH tends to be higher in baleage compared to chopped silage. Inoculants can improve fermentation and are generally recommended for baled silages.

Losses are minimal and nutrient retention is excellent in well sealed silage bales (see Figure 15A-1).

Plastic Materials for Storage

There are several methods for using plastic materials to produce round-bale silage:

Individually Wrapped Bales –
Bales normally have 6 to 8 wraps of plastic rolled around them to create an effective seal against oxygen. The individually-wrapped bale has the advantage of portability and versatility, but these bales often must be baled at slightly lower moisture to prevent seepage out of the bale, which then allows oxygen penetration. To date, polyethylene plastic, 4 to 9 mils in thickness, has become the common bale cover material. New, low-oxygen permeability plastics are coming onto the market. These new plastics combine polyethylene with either polyamide or EVOH to create barriers that are 18 to 400 times less permeable to oxygen. The cost of these new low-oxygen permeability plastics is much greater than traditional plastic, but it takes fewer wraps to seal an individual bale.

FIGURE 15A-1

Moisture, DM loss, and nutrient retention in large round and large square bales of first-cutting alfalfa silage bales after 157 days of storage

	Moisture %		DM Loss	Nutrient Retention % of initial concentration		
Large Round Bale	**Initial**	**Final**	**% of Total**	**CP** [1]	**ADF** [1]	**NDF** [1]
High - Moisture/Individually Wrapped	56.1%	56.6%	2.1%	104%	105%	109%
Low - Moisture/Individually Wrapped	38.1%	39.0%	3.0%	108%	117%	115%
High - Moisture/Tube Wrap	54.9%	56.4%	4.9%	114%	110%	108%
Low - Moisture/Tube Wrap	39.3%	40.4%	2.7%	101%	102%	103%
	Moisture %		**DM Loss**	**Nutrient Retention % of initial concentration**		
Large Square Bale	**Initial**	**Final**	**% of Total**	**CP**	**ADF**	**NDF**
High - Moisture/Individually Wrapped	48.2%	50.8%	6.2%	117%	110%	102%
Low - Moisture/Individually Wrapped	35.9%	38.6%	3.6%	118%	110%	107%

[1] CP = Crude Protein, ADF– Acid Detergent Fiber, NDF – Neutral Detergent Fiber
Adapted from: Shinners, K.J., B.M. Huenink, R.E. Muck, and K.A. Albrecht. 2009. Storage characteristics of large round and square alfalfa bales: Low-moisture wrapped bales. Transactions of the ASABE, Vol. 52(2):401-407.

Plastic Tubes – Some machines allow stuffing several bales in a long plastic tube which is then sealed at both ends. This method uses only between one half and two thirds of the plastic as individually wrapped bales. The system can be effective and time saving, because one person can complete the process compared to two people normally for individually wrapped bales. One drawback with bale tubes is that more bales may spoil if the bag is torn, punctured, or opened for feeding out. However, the tubes can be easily tied off into convenient segments for feeding.

Individual Bags – Bags come in various lengths, diameters and thicknesses. A spear device is needed to lift the bale while applying the bag. Then, the bale is placed in storage position before tying off. If possible, bales should be stacked in a cordwood pattern to reduce exposed surface area. An additional stack cover of netting or plastic may reduce storage damage. Individual bags do not exclude as much oxygen as individually-wrapped bales.

Sheet Plastic – Several bales can be stacked under two sheets of plastic, with the plastic ends on the ground covered with soil, sand, or other effective sealing procedures. The problem with this type of storage is that there are more possibilities for air leaks to develop, which may result in a large number of bales being spoiled.

Recommendations on Baleage Production

(1) Harvest at the proper stage of maturity, just as you would with normal hay making.

(2) Mow in the morning after the surface moisture has evaporated. This timing permits carbohydrates to increase in the leaves and be more readily available to bacteria.

(3) Mowing-conditioning can be done with the same equipment as for harvesting hay. Raking may be eliminated but if included, rake into single windrows after dew has evaporated the following day.

(4) Bale into uniform, dense bales after forage has dried to 40% to 60% moisture depending on the hay crop.

(5) Consider adding a proven silage inoculant to the windrow as it rides over the pickup. Inoculation should be effective, if properly applied, in retarding mold growth and stimulating desirable fermentation.

(6) The ground speed of the baler should be less than speeds used in making field-cured hay. Slower speed results in a tighter, denser bale, which will wrap or pack more easily and allows less oxygen penetration. The goal is a dry matter density of 10–12 pounds per cubic foot.

(7) Bales should be of the correct size. Normal baleage diameters are 42″– 48″ due to weight of the bale. Be aware of the capacity of your baler and bale-moving equipment.

(8) Tie bales using natural fiber or synthetic twine, discharge them from the baler, move them by spear-type bale mover to the storage area, which should be accessible and should allow for good drainage. Enclose and seal bale as soon as possible after formation.

(9) Periodically check bags for leaks, and patch any holes with tape.

CHAPTER 16

Considering Grazing Systems

Since biblical times, pasture has been the foundation of grassland farming. In the U.S., pasture systems have gained renewed interest among small and medium sized farms looking to maximize their returns from marginal ground.

While this handbook focuses on the production of high-quality hay, most ruminant livestock operations use a combination of production systems to meet their forage needs. Grazing systems offer an alternative for harvesting high-quality forage from marginal lands as well as increasing the productive capacity of pastures. If you plan to supplement hay production on your farm with grazing, you can gather more information on a specific pasture system through your state's Cooperative Extension Service or Natural Resource Conservation Service (NRCS).

Pasture Systems

When considering forage feeding systems, remember that since biblical times, pasture has been the foundation of grassland farming. The Food and Agriculture Organization (FAO) estimates that slightly less than half the world's usable surface is covered by grazing systems, and these grazing systems support approximately 360 million cattle and over 900 million sheep and goats (source: FAO; accessed at http://www.fao.org/docrep/x5303e/x5303e00.htm.).

In the U.S., pasture systems have gained renewed interest among small and medium sized farms looking to maximize their returns from marginal ground. While some pasture systems may be less efficient in terms of forage utilization than other feeding systems, they do not require extensive investments on the part of the grower. And, with good management, pasture can be relatively efficient, especially when adapted to non-tillable acreage.

Pasture has always supplied most of the feed for beef cows and sheep throughout the U.S. But, new year-round pasture programs including both permanent pasture and partial total mixed rations (TMRs), or large round hay bales fed in place or in feed lots, have given pasture an even bigger boost in many states.

Here's a rundown on various pasture systems:

Continuous is the oldest, but least efficient method of grazing, especially with taller-growing pasture species. Continous grazing consists of allowing open access to the entire pasture at all times by all animals during the entire grazing season (or year-round). This strategy allows animals to be very selective in their grazing pressure, which wastes forage, promotes ground erosion, and weed infestation. Despite its lack of efficiency, it's still the most widely used system, especially on many permanent pastures, because it takes little to no management or time.

Heavy Grazing Followed by Resting appears to be a good system of managing permanent bluegrass pastures. This type of system consists of having several pastures, which are often used on a seasonal basis (i.e., a spring pasture, a summer pasture, and a fall pasture). Again, these systems lack efficiency, but require little management.

Rotational Grazing is a system where animals are moved from pasture (or paddock) to paddock on a regular basis to capture more high-quality forage and allow more frequent resting or recovery of pasture. There are several versions of rotational grazing, and each version requires more management and investment in fencing than continuous grazing. But, rotational grazing permits better utilization of the crop, especially with taller growing pasture crops, and it will provide forage at a lower cost than either strip grazing or green chopping.

Essentially all rotational grazing systems increase the number of paddocks and decrease the number of days that animals access an individual paddock.

High Stock Density or Mob Grazing may be the most controversial grazing method today, but can offer benefits to some operations. This method involves grazing large numbers of livestock in a confining pasture and allowing them to consume the available forage before moving them to another pasture. This method requires intensive management; failing to move livestock at the appropriate time may adversely affect animal production. The high animal concentration can cause soil compaction issues, reducing the permeability of both air and water, while also depleting the soil's organic matter. However, when properly managed, the system works well when reclaiming fallow pasture lands or when addressing weed infestations. Mob grazing provides for more complete utilization of available forages, and it also improves soil-nutrient distribution.

Fence-Line or Strip-Grazing is another more intensive and usually more efficient system than rotational grazing, especially when a back fence is used to keep cattle off the grazed area. Within an individual paddock, temporary electrified fences are moved on a daily basis to allow cows access to fresh grass. The size of the strip is dependent on the number of cows, the height of the pasture grass, the final grazed height desired for plant regrowth, and access to water. Often, strip-grazing is combined with rotational grazing to improve efficiency and use of multiple species of legumes and grasses within a paddock system.

First and Second Grazers is a method to allow different classes of animals to graze forage of highest quality. In this system, animals with greater energy requirements (first grazers) are allowed first access to the pasture. After they have grazed off the highest quality portion they are moved to the next pasture. A second group of animals (second grazers) with lower energy

requirements, often heifers and horses, are given access to the residual herbage in the first pasture.

Forward Creep Grazing is similar to the system of first and second grazers concept, in that the animal requiring highest energy is given first choice. The difference is that two or more classes of livestock, such as cow-calf or ewe-lamb, are group grazed and a physical barrier is placed to allow preferential movement of the higher-producing animals into the next pasture in the rotation scheme.

Stockpiling is another approach to cashing in on pasture, especially for beef or sheep. Stockpiling simply means allowing forage to accumulate in the field until it is needed for grazing, and it works well with such species as tall fescue. As with all pasture systems, for stockpiling to pay off, careful management is needed. Stockpiling only works with select species. Tall fescue is an excellent stockpile species, and if your farm is in a region where tall fescue grows well, stockpiling is an excellent way to extend the grazing season into the winter.

Irrigated Pastures – The use of irrigated pastures has increased in the past decade to extend the grazing season, especially during the late summer. These systems have a high potential in ranching areas where large-scale beef cattle production is practiced and where irrigated pasture can be used to complement other forage resources. Irrigated pastures for dairy cattle have been introduced in the southern U.S. In Florida and Georgia, cows are now grazed under pivot irrigation systems to both allow for greater grass regrowth and to cool cows during daytime grazing. Irrigation requires the use of appropriate grasses and/or legumes, a high soil fertility, and sound grazing management to provide the greatest return on investment.

Green chopping, also called "green feeding," "soiling," "zero grazing," or "mechanical pasturing," consists of growing a succession of forage crops, including perennials and annuals if needed, harvesting them with mechanical equipment, and hauling the green feed to the cattle.

Green Chopping, also called "green feeding," "soiling," "zero grazing," or "mechanical pasturing," is the most intensive form of "pasturing." This system consists of growing a succession of forage crops, including perennials and annuals if needed, harvesting them with mechanical equipment, and hauling the green feed to the cattle rather than allowing the cattle to harvest their own forage. Green chopping has lost favor over the past decade as equipment and fuel costs have risen, thereby decreasing potential profit margins.

Advances In Pasture Plant Species

Traditionally, we have focused on alfalfa, clovers, and perennial grasses such as blue or Bermuda grasses and orchard grasses for pastures. However, the advent of annual grasses and grains and new varieties of perennial grasses have provided much greater gains and extended grazing seasons in many regions of the U.S.

• Endophyte-free tall fescues are now common in the market. These varieties cross the good agronomic qualities of tall fescue with greater palatability and digestibility due to lower levels of the endophytic fungus and perloline alkaloid, two substances that plagued older, tall-fescue varieties.

• Low alkaloid reed canary grass vareties, like *Palaton* and *Venture,* are now well recognized as very productive, persistent cool-season pasture grasses.

• Highly nutritious *perennial ryegrass* (also known as Italian ryegrass) is the most widely used cool season pasture grass in much of Europe, New Zealand, and southeastern Australia. The development of more hardy tetraploid varieties has made this species a mainstay in many northern pastures. These grasses exhibit very high digestiblity and high sugar contents, which make them valuable for grazing high-producing dairy cows.

• Brassica species such as rape, kale, turnips, and swedes are rapidly gaining ground to extend grazing seasons especially into the late winter in the northern regions of the U.S. These highly nutritious annuals or biennials are now recognized in many areas of the U.S. and Canada as valuable supplemental summer and winter pasture crops, especially for beef and sheep.

Other Pasture System Improvements

• No-till seeding equipment has improved to the point where pastures can be rapidly improved even within the grazing season by the seeding of annuals into old sods. The no-till technique also works well for seeding brassica species into old sods.

• Fencing systems have improved dramatically in the last decade with new high voltage/low current, solar-powered, portable fences that allow pastures to be divided rapidly to account for changes in weather or animal numbers. These new fences are relatively low cost in comparison to the traditional multi-strand high-tensile fencing systems for permanent pastures.

CHAPTER 16A

Hay Crop Silage

While this book is focused on making dry hay, there are an increasing percentage of dairy farms in the U.S. making hay crop silage, and it would be remiss not to include a chapter on the proper techniques for making good quality hay crop silage. There is no discernable difference in milk production whether dairy cows are fed hay, silage, or pasture as long as the forage is of good quality and the cows receive enough of the feed. Since storing feed as silage and hay often makes it possible to get more forage from fewer acres, this system now drives many feed programs. Silage is defined as "A moist feedstuff preserved by the formation of acids during an anaerobic (without air) fermentation." The fermentation process has four distinct phases before silage become stable within the storage structure.

Phase 1 is respiration, which starts when the plant is cut and continues for several hours as the plant cells use up their oxygen supply. During this time, aerobic bacteria (those that need oxygen to live) on the surface of the plant convert sugars and oxygen to CO_2, heat and water. The heating and continuing respiration of the plant cells cause enzymes within the plant to break down some of the plant proteins. The goal of reducing oxygen trapped in the silage mass works to reduce the length of respiration and improves protein quality within the silage. Phase 1 normally lasts less than 24 hours after the hay crop is placed in the silo.

There is no discernable difference in milk production whether dairy cows are fed hay, silage, or pasture as long as the forage is of good quality and the cows receive enough of the feed. Since storing feed as silage and hay often makes it possible to get more forage from fewer acres, this system now drives many feed programs.

Phase 2 is acetic acid production, which occurs as the oxygen is depleted in the silage mass and the anaerobic bacteria (those that live without oxygen present) begin to grow and start the fermentation conversion of sugars to acetic acid (i.e., vinegar). The acetic acid rapidly lowers the pH down to around 5 at which point the enzymes responsible for protein breakdown stop working preventing further protein degradation. However, as the acetic acid accumulates and pH drop continues over about a 24 hour period, the acetic acid-producing bacteria decline in numbers because they do not like a low pH environment.

Phase 3 This pH drop allows lactic acid-producing bacteria to grow and convert plant carbohydrates to lactic acid, acetic acid, ethanol, mannitol, and CO_2. This phase is much slower, lasting three to six days.

Phase 4 is the continuation of phase 3, with peak production of lactic acid and less production of the other fermentation end products. Phases 3 and 4 together normally take two or three weeks (Day 3 to 21 in Figure 16A-1) until the pH is low enough to stop all bacterial growth, including the lactic-acid-producing bacteria.

Storage When phase 4 is complete after about 21 days, the silage will be stable enough within the storage structure until feedout. The final pH of the hay crop silage will range between 4 and 5.5, depending on its moisture content. (Wetter silages normally have lower pH than drier ones.) The lactic acid is a much stronger acid and it will continue to drive down the pH of the silage mass.

Moisture ranges for various silage types are: (1) high moistures or direct-cut silage, 70% and above, (2) wilted silage, 60% to 70%; and (3) low moisture silage or "haylage," 40% to 60%. See Figure 16A-1.

Other things being equal, wilted and low-moisture silage and barn-dried hay strike the best balance between harvest and storage losses. To achieve the greatest benefit from ensiling forage, the following five factors are crucial control points:

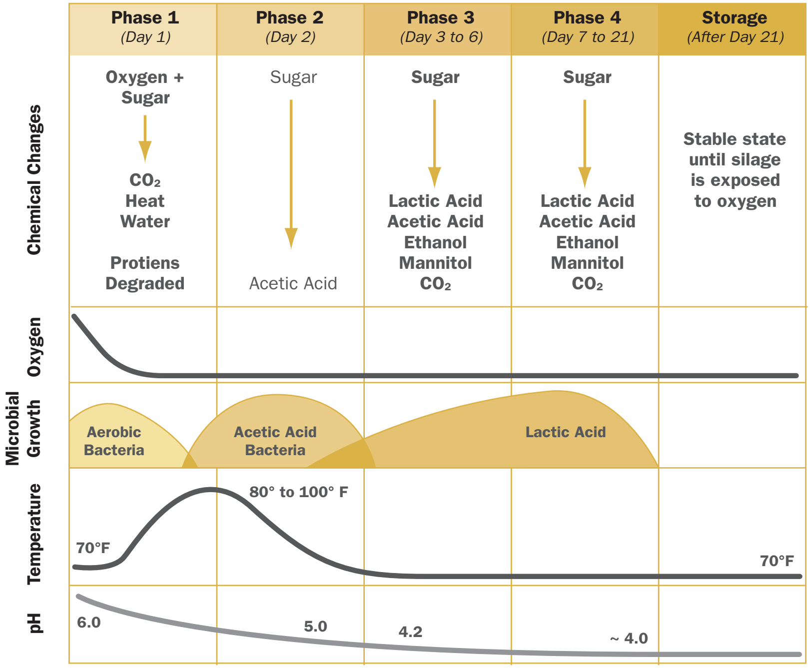
1. Forage moisture content – determined by the forage and storage structure being used.
2. Fineness of chop – based on the forage and animal being fed.
3. Exclusion of air – NECESSARY FOR OPTIMAL FERMENTATION
4. Forage carbohydrate (sugar) content – Legumes and grasses tend to have higher sugar content than corn silage. Higher sugar content allows better bacterial growth and greater fermentation.
5. Bacterial populations, both naturally occurring and supplemental – Corn silage has a larger population of naturally-occurring bacteria that promote fermentation than legumes or grasses, and therefore, are less likely to need supplemental bacterial inoculants for adequate fermentation.

Direct-Cut Silage

Early cut legumes and grasses may contain as much as 80% to 85% moisture at harvest. Ensiling this wet material in silos or bags results in excessive deterioration of protein, undesirable odor in silage, seepage, and deterioration of concrete in silos. Direct-cut silage fed as the major forage usually results in lower consumption of dry matter and

FIGURE 16A-1

The four phases of normal silage fermentation



Source: Jones, C. M., A. J. Heinrichs, G. W. Roth, and V. A. Ishler. 2004. From Harvest to Feed: Understanding Silage Management. Penn State Cooperative Extension Publication UD016.

lower livestock production than comparable, well-preserved wilted or low-moisture silage or hay. The lower dry matter intake is due to the presence of unpalatable fermentation end products such as butyric acid, which produces an extremely noxious odor that does not rapidly dissipate. These direct-cut silages can also contain less energy due to losses of sugars during fermentation and seepage.

When making direct-cut, high moisture silage, the following procedures should reduce losses during storage:

1. Regardless of the plant species, focus on cutting at the appropriate stage of growth and moisture level.

2. Avoid cutting when wet with dew or rain.

3. A longer theoretical length of cut (TLC), up to 3/4-inch, may be used to slow the release of plant moisture during the ensiling process.

4. Provide drainage for excess juice or leachate. European systems that acidify the silage will collect this material and attempt to use it as a liquid feed for cattle. The formic acid treatment system in Europe has not been adopted in the U.S., given the corrosive nature of the acid and problems with palatability of the silage and leachate. Most states in

the U.S. require a leachate containment system for silos to prevent environmental pollution problems, and the costs of these systems can be prohibitive.

5. Add preservatives or additives to improve quality of direct cut forage. Beet pulp, soybran flakes, corn and cob meal or other highly absorbent materials absorb forage moisture and reduce seepage. However, the additional labor and equipment costs to mix these by-products into the forage during harvest limit their use. Inoculants can be used to improve the fermentation process and are highly recommended. See the descriptions of these products in the following section.

6. Distribute evenly in silo, particularly the top, and pack thoroughly to increase density and limit fermentation, storage, and feedout losses.

7. Cover and seal the silo with plastic or other suitable material to prevent oxygen exposure that will increase storage and feed out losses. There is a system available in the U.S. to vacuum oxygen out of small silos or piles of direct cut forage and improve the fermentation http://www.alphaag.com/Home/tabid/37/List/1/Default.aspx). However, these systems are limited to smaller piles, silos, and bags.

Wilted Silage

Higher quality silage is obtained by wilting the crop to 60% to 65% moisture levels. Wilting gets rid of some water in the field, so less is handled. Odor and silo leaching problems are also reduced and preservatives may not be needed. Wilting may result in slightly higher field losses than cutting direct, but this is more than offset by higher quality feed and higher dry matter intake by animals.

The following procedures are recommended for making wilted silage:

1. Cut at early stage of plant growth.

2. Wilt 1 to 12 hours, depending on the desired moisture level and weather.

3. Rake while still above desired moisture to retard further drying.

4. Use an appropriate TLC (3/8 to 3/4 inch setting) on the forage harvester. The TLC should be set to produce a particle size distribution appropriate for the animal to which the hay crop will be fed. Penn State University developed a particle size determination system (a.k.a. Penn State Particle Separator or shaker box) for silages and total mixed rations that is widely accepted as the preferred method for evaluating particle size in the field. For more information, visit: www.das.psu.edu or contact your local cooperative extension office.

5. Begin filling while still on the wet side to allow for longer drying period for the last material of each lot cut.

6. Fill silo rapidly; continuously if possible. When silo filling is delayed or interrupted for extended periods of time (i.e., greater than 12 hours), the silo surface should be covered with plastic to reduce oxygen exposure that will cause greater storage losses and more spoilage of ensiled material.

7. Add preservative or additive if desired (not normally needed for wilted material). A description of silage inoculants and additives is provided in the following section.

8. Distribute as evenly as possible within the silo, particularly the last few feet.

9. In upright silos, the top layer should be leveled and tamped down if possible. MAKE SURE APPROPRIATE SAFETY MEASURES ARE TAKEN DUE TO THE PRESENCE OF HAZARDOUS SILO GASES. In bunker silos, pack the material as it is placed in the silo to remove as much oxygen as possible. This will improve the fermentation process, producing better quality silage. Packing is not necessary in upright silos due to the self-packing characteristics of the silo.

10. Cover and seal with plastic or other suitable cover to prevent oxygen exposure that will impede fermentation and increase storage and feed out losses.

11. Allow at least 21 days for fermentation to occur prior to opening and feeding out of the silo. When opening a silo, make sure proper ventilation is applied to the silo first to remove any trapped silo gasses, which are hazardous to breath.

Low-Moisture Silage

"Haylage," "dry silage," "high dry-matter silage" and "heavy-wilt silage" are other terms given to forage ensiled at a moisture of 40% to 60%.

Advantages for properly harvested and stored low-moisture silage include less water weight to handle and fewer nutrient losses in storage.

The major challenge to ensiling material at these lower moisture levels is the failure to exclude air, which will lead to serious heat damage and a marked depression in the digestibility of the protein and non-structural carbohydrates in the ensiled crop. The depression in protein digestibility varies with the degree of heating, but can exceed 25% to 30%.

What causes heat damage, which is often referred to as carmelization? The answer is chemical oxidation (burning) of the sugars in the forage. The sugars will react with and bind to the protein in the forage, thereby reducing digestibility of both the protein and the sugar. If excessive air is trapped in the forage, or outside air is permitted to enter through loosely packed material, oxidation proceeds rapidly, causing a large amount of heat to build up within the silage mass.

Exclusion of air by thorough packing and proper sealing of the silo is the best way to prevent heat damage. The following are recommendations on making better quality low-moisture silage:

1. Harvest at the proper stage of maturity – early bloom for legumes – early heading for grasses.

2. Maintain proper moisture (40% to 60%).

3. Low-moisture silages are often chopped at shorter TLC (3/8 to 1/2-inch) to increase packing density and reduce oxygen trapped in the silage. Keep chopper knives sharp and set close to the shear bar.

4. Provide a tight silo. Older silos should be reconditioned, if necessary, and/or calked and sealed. Oxygen-limiting silo or sealed, bottom-unloading silos are specially designed for these types of silage. However, they will have a higher capital cost than traditional top-loading concrete silos. Low moisture silages are NOT recommended for bunker silos because they cannot be sealed as fully as upright silos.

5. Fill silo rapidly and continuously if possible. Add preservatives or additives if desired.

6. Distribute evenly in silo using a mechanical distributor if possible.

7. In top-unloading, upright silos, crown center slightly and cover and seal with a plastic silo cap.

8. Allow at least 21 days for fermentation to occur prior to opening and feeding out of the silo. When opening a silo, make sure proper ventilation is applied to the silo first to remove any trapped silo gasses, which are hazardous to breathe.

Failure to follow the above directions can result in heavy feed value losses and cause personal safety issues.

Silage Inoculants and Additives

Inoculants, preservatives or additives are NOT substitutes for good silage-making practices. But, they may improve fermentation and stabilize silage during feed out when harvest and storage of hay crop for silage is compromised by weather or other conditions. Silage additives fall into three major groups: (1) Inoculants – cultures of specific microbial organisms, (2) organic or mineral acids that rapidly lower pH, and (3) those supplying a source of readily available carbohydrates.

Higher quality silage is obtained by wilting the crop to 60% to 65% moisture levels. Wilting gets rid of some water in the field, so less is handled. Low moisture silages are often chopped shorter to increase packing density and reduce trapped oxygen.

Here's a very brief rundown on each group and where they may fit in your program:

Microbial Cultures include bacterial and yeast cultures, enzymes, certain acids or salts of these acids, antibiotics, and mold inhibitors. While these products are very popular, they provide limited benefit when silage is harvested under optimum conditions. But, under sub-optimal conditions, these products can save a crop and prevent problems during harvest and feed out.

There are two types of bacteria, homolactic and heterolactic, used in bacterial inoculants. Homolactic bacteria, such as *Lactobacillus plantarum, Enterococcus faecium,* and several species of *Pediococci,* produce only lactic acid during fermentation. The rapid production of lactic acid helps to quickly lower the pH of the silage and inhibit the growth of undesirable bacteria such as *Clostridia* or *Enterorbacter* species. Heterolactic bacteria, such as L. buchnerii, convert lactic acid to acetic acid. The benefit of these types of bacteria is that the acetic acid helps to stabilize the silage during feed out. When the silo is opened, the exposure of the silage to oxygen allows the rapid growth of yeasts and molds when the air temperature is above 70°F. The yeast and mold growth cause the silage to heat and spoil. Acetic acid inhibits the growth of yeasts and molds, thereby limiting the heating and spoilage of the silage during feed out. Homolactic inoculants are good choices when feed out issues will be minimized, such as a silo that is fed out during the winter months. Heterolactic inoculants are important when silos will be fed during warmer weather (above 70°F) to reduce silage heating from yeast and mold growth.

When choosing a bacterial inoculant, make sure that the product is backed by university-conducted research that has been published in refereed scientific journals (e.g., *Journal of Dairy Science, Journal of Animal Science, Animal Feed Science and Technology*). Not all inoculants work in all situations, and given the myriad of products in the market and the costs of these products, it is essential to ask when these products work and when they don't work. The better companies will provide documentation for both cases to ensure that their products are properly used.

Bacterial inoculants may be applied as either a dry product or wet product. If a dry product is used, then the forage being harvested must have sufficient moisture to promote adequate bacterial growth. Follow company instructions as closely as possible to ensure good growth and improved fermentation.

Adding anhydrous ammonia to corn silage and other forages became popular during the 1970's and continued to be used widely into the 1990's. However, the popularity of the practice has waned due to costs and safety issues. When properly applied, ammonia increases protein levels, improves digestibility, and improves bunk life. In essence, ammonia sterilizes the forage because ammonia is toxic to yeast and molds that cause spoilage. Adding nitrogen to corn silage in the form of urea is another alternative, but can lead to protein solubility issues when mixing is not complete.

Chemical Acids include such products as propionic and formic acids as well as certain mineral acids. Mineral acids lower the pH immediately, while organic acids have a limited effect on lowering pH. But both limit microbial growth and help stabilize silage. All forms of acid preservation are normally more costly than inoculants, and provide only short term preservation during feed out.

Readily Available Carbohydrates include corn and cob meal, citrus pulp, beet pulp, molasses, dried whey, and similar products. These may be mixed with high-moisture legume or grass forage at ensiling to improve fermentation. The carbohydrates are rapidly converted to lactic acid and help to lower the overall pH. The carbohydrate source is not completely utilized for fermentation with 75% to 85% of the material remaining as a nutrient source in the feed. However, if mixing is not complete, then fermentation will not be even throughout the silo, resulting in variable silage quality. One additional benefit of the dry, bulkier feeds is the absorption of some moisture from the high-moisture forages, which will reduce seepage.

Silage Storage Methods

There are four storage choices for silage: *conventional upright silos, horizontal silos or piles (i.e. bunker silos or trenches), oxygen-limiting silos, and plastic bags*. Figure 16A-2 summarizes the recommended moisture levels for various silages with different storage systems.

Conventional Upright Silos are the gold standard for silage storage, provided they are well maintained. Dry matter losses are normally the lowest and long term payback is normally better with conventional, upright silos. The negatives often associated with upright silos are the need to maintain the interior silo surface that will be slowly eaten away by the

FIGURE 16A-2

Recommended moisture content of silage crops for different storage structures

Storage Structure	Alfalfa	Grass	Corn Silage	Small Grain Silage
Horizontal silo	65% - 70%	65% - 70%	65% - 70%	60% - 70%
Conventional Upright silo	60% - 65%	60% - 65%	63% - 68%	63% - 68%
Oxygen-limiting upright silo	40% - 55%	40% - 55%	55% - 60%	55% - 60%
Bag	60% - 70%	60% - 70%	60% - 70%	60% - 70%
Baleage	50% - 60%	50% - 60%	—	—
Pile or Stack	65% - 70%	65% - 70%	65% - 70%	60% - 70%

Adapted from: Jones, C.M., A.J. Heinrichs, and V.A. Ishler. 2004 Frome Harvest to Feed: Understanding Silage Management, Penn State Cooperative Extension Publication UD016.

silage acids, and the slower rates of filling and feed out for larger dairy herds.

Horizontal Silos have become very popular as herd sizes have increased due to the ability to rapidly fill or feed from these systems and their lower capital investment. Horizontal silos often come into play when a dairy herd tops 150 cows or more. The drawbacks on horizontal silos are the increased DM losses and the greater management requirements during feed out to reduce losses.

Oxygen-limiting Silos became popular in the 1970's because they reduced spoilage losses, especially in legume and grass silages. However, as other silage making practices improved, the higher capital cost, increased maintenance costs, and relatively slow feed out rates reduced the popularity of these silos. In fact, today many old metal, oxygen-limiting silos are converted to top-unloading, conventional silos by cutting doors into the sides.

Plastic Bags – The attributes of using plastic to preserve forage was described to some degree in the round bale chapter. It must be noted that silage bags have become very popular for all sizes of farms. The major benefit with a silage bag is flexibility in size and location. Losses tend to be similar to well managed horizontal silos, but the cost of plastic will increase with time. Storage length is normally limited to one year because UV radiation from sunlight will degrade the top surface of the bag, causing cracking and eventual air infiltration, which will lead to spoilage.

One caution, however, if you are storing hay-crop silage in either a conventional, horizontal, or oxygen-limiting silo or bag. Toxic gasses, nitrogen dioxide (NO_2) and carbon dioxide (CO_2) are sometimes produced during the first few days after filling. NO_2, a reddish brown-colored gas, is heavier than air and tends to settle inside silos or be found coming down silo chutes. It is highly toxic to humans and animals. CO_2 is colorless and heavier than air and, if present, tends to collect in low places. It forms shortly after filling begins and continues until fermentation stops. A person entering a silo in which silage has settled below the open door could suffocate from lack of oxygen.

A simple precaution for operators to follow is to never enter a recently filled silo without running the blower into the silo for a MINIMUM of 30 to 60 minutes or otherwise providing for adequate ventilation.

Feeding

Hay as a Livestock Feed

Animal nutritionists are placing ever-increasing emphasis on maximizing forages in livestock rations. The high producing dairy cow is the most responsive to hay quality due to her high demand for nutrients.

Depending on the livestock operation, the cost of feed represents 50% to 75% of the total production costs. Forages produced on the farm should be the most cost effective feeds available. As a result, animal nutritionists are placing ever-increasing emphasis on maximizing forages in livestock rations. This emphasis is due to the combination of important nutrients forages provide, environmental considerations such as soil conservation, and agronomic advances in yield potential.

Hay's Role in the Ration

In most ruminant and equine rations, hay is primarily a source of energy and fiber and secondly a source of protein. However, we know that the protein content of high-quality legume forages also makes a significant contribution to the animal.

In simple-stomached, non-ruminant animals (e.g., pigs, poultry, dogs, cats, etc.) that are not able to digest fiber, forages may be fed as a source of protein (such as dehydrated alfalfa pellets), vitamins and minerals. Ground hay or pasture can also be used to replace a portion of the feed grains in the diet of gestating brood sows and certain other animals. In recent years, fiber has become an

FIGURE 17-1

Comparative economic values of the nutrients from alfalfa hay, corn silage, corn grain, whole cotton seed, and soybean meal based on aggregate market prices from Pennsylvania [1]

	Alfalfa Hay *(avg. quality)*	Corn Silage *(Normal)*	Corn Grain *(Dry Ground)*	Cotton Seed *(Whole, Linted)*	Soybean *(Meal)*
Nutrient Composition[2]					
Dry Matter *(DM)* %	90.3	35.1	88.1	90.1	89.5
Metabolizable Energy *(ME)* Mcal per lb of DM	0.89	1.06	1.42	1.32	1.55
Neutral Detergent Fiber (NDF), % of DM	41.9	45	9.5	50.3	9.8
Crude Protein (CP), % of DM	19.2	8.8	9.4	23.5	53.8
Market Price Per					
As Fed Ton1	$135	$32	$140	$275	$335
Mcal of ME	$0.084	$0.043	$0.056	$0.116	$0.12
Lb of NDF	$0.178	$0.101	$0.836	$0.303	$1.91
Lb of CP	$0.389	$0.518	$0.845	$0.649	$0.35
Nutrient Value					
Total Value of 100 lbs of DM[3]	$9.14	$9.42	$9.82	$14.32	$18.55
Anticipated Yield per Acre	5 tons	20 tons	150 bu.	1,000 lbs	40 bu.
Total Nutrient Value per Acre	$825.34	$1,318.80	$726.72	$129.02	$318.76

1- Prices from "Feed Price List" accessed on June 7, 2010 at http://www.das.psu.edu/research-extension/dairy. Prices used are approximate and represent aggregated prices for the State of Pennsylvania. Prices are on a commodity basis, and represent farm-delivered, full tractor-trailer loads (TTL) prices.
2- Nutrient composition values from the National Research Council (NRC), 2001, Nutrient Requirements of Dairy Cattle, 7th Revised Edition.
3- Determined using current market prices and SESAME™ software developed at The Ohio State University, http://www.sesamesoft.com/.

increasingly important part of companion animal diets for dogs and cats, but the type of fiber used is often refined from straw and woody materials. Given the small size of the market for forages in simple-stomached, non-ruminant animals, those interested in pursuing these markets should contact the companion animal specialists at their state's land grant university.

Because of the changing prices of feeds and of different harvesting methods, care must be exercised in comparing different types of feeds on an economic basis. However, Figure 17-1 compares the economic value of metabolizable energy (ME), neutral detergent fiber (NDF), and crude protein (CP) in alfalfa hay, corn silage, corn grain, whole cottonseed, and soybean meal. From the whole farm perspective, it's also important to compare these crops on a per acre basis.

In terms of the economic value of the energy, fiber, and protein provided by the different feeds, alfalfa hay had a total nutrient value nearly 93% (9.14 ÷ 9.82 x 100) that of corn grain and 97% of corn silage. Not considered in this comparison is any cost difference to produce, harvest, or store the crop, or labor in feeding. It should also be emphasized that the comparisons are valid only if the energy, fiber, and protein supplied by the different types of feed are actually needed in the ration. In other words, the value of feeds may change depending on the needs of the particular animals.

In terms of energy produced per acre, corn silage leads all other feeds because of the digestibility of both the starch and fiber in the whole plant. Where corn can be grown successfully, production of almost any beef or dairy operation would be reduced without it. However, as we look at the economic value of the energy, fiber, and crude protein from one acre of each feed, it's obvious that alfalfa hay can be extremely competitive when high quality and high yield are obtained simultaneously.

The Key Is Quality

The economic figures in Figure 17-1 do not account for the quality of the hay in nutrient value. Quality is usually represented by the concentrations of fiber and protein in the hay and is most affected by the maturity of the crop when it is harvested. Other factors come in to play, however, such as field weathering or the effects of different harvest-storage methods. These are discussed in other chapters.

The value of quality is extremely important, especially in dairy rations. Figure 17-2 shows the effect of alfalfa maturity level at harvest on milk production in dairy cattle. The earlier the cutting, the higher the quality and the more milk can be produced, regardless of the amount of grain fed. The early

Looking at the economic value of crude protein and TDN from an acre of each feed, hay can be extremely competitive to corn silage when high quality and high yield are combined.

cut hay is higher in protein and lower in fiber than hays of more advanced maturity. In addition, the fiber is more digestible, which affects the level of intake.

Classical work by Oba and Allen (1999) illustrated that, as the digestibility of forage NDF increased, the intake and corresponding milk production increased. For every 1% unit increase in NDF digestibility in the ration, there is a corresponding 0.37 pounds increase in DM intake and 0.55 punds increase in milk production per cow per day. (Oba, M., and M. S. Allen. 1999. Evaluation of the Importance of the Digestibility of Neutral Detergent Fiber from Forage: Effects on Dry Matter Intake and Milk Yield of Dairy Cows. J. Dairy Sci. 82:589–596.)

Although the high producing dairy cow is the most responsive to hay quality due to her high demand for nutrients, hay quality is certainly important for other classes of livestock as well. For example, a 1,100-pound beef cow of average milking ability would require about 30 pounds of a mature orchard grass hay to meet her energy needs, an amount above her intake capacity. However, when offered an early bloom orchard grass hay, she could easily consume the 21 pounds of hay required to meet her energy demands. These differences are also reflected in sheep and equine rations.

High Intake Critical

The voluntary intake of feed by ruminant animals accounts for up to 75% of the variation in digestible nutrient consumption. Compared to concentrates, hay has a rather low energy density due to its higher fiber level (see Figure 17-1). Therefore, the goal in ration formulation is often to maximize forage level in the ration without reducing total energy intake. This brings us back again to the overriding importance of hay quality, the primary factor of how much an animal will consume.

Farmers often find that at comparable maturity, ruminants consume higher levels of legumes than grasses. This relates to their structural makeup, with legumes having a lower proportion of fibrous cell wall (referred to as "NDF") than grasses. Since hay fiber physically takes up space in the

FIGURE 17-2

Milk Production as Related to Alfalfa Maturity & Level of Concentrate Fed

	Concentrate	Alfalfa Maturity (Bloom)			
Measurement	**% of DM**	**Pre**	**Early**	**Mid**	**Full**
4% Fat Corrected Milk, LB/DAY	20	79.6	68.0	57.2	52.1
	37	83.2	69.1	62.5	64.7
	54	87.1	77.2	66.2	64.7
	71	86.0	77.2	64.7	69.5

Source: Kawas, J. R., N. A. Jorgensen, A. R. Hardie & J. I.. Danelon, 1983. Change in feeding value of alfalfa with stage of maturity and concentrate level, J. Dairy Sci. 66(Suppl. 1):181. (Abstr.)

rumen, the higher NDF of grasses means that the animal will feel full on a lower volume of hay, and intake will be limited compared to legumes. Additionally, higher NDF levels result in a reduced rate or speed with which the forage particles are digested and passed out of the rumen. Thus, legume forages are digested and leave the rumen faster than grasses, allowing the animal to eat more total feed. Remember, however, that within a forage specie, *maturity is the most important factor regulating NDF or fiber level*. Once again we come back to the same message, *whether legume or grass, cut early for high quality.*

Forages have changed considerably over the years but so have the animals. Today, the average cow will consume nearly twice as much feed dry matter on a daily basis compared to cows from the 1950's. So, cows now have the ability to eat more forage, which makes it critically important to produce high-quality forage so that intake is not limited and performance will not suffer.

The "Scratch Factor" in Hay

It is well known that the long physical form of hay may limit its intake by the ruminant animal. The question is then why not mechanically process the hay to cut down its particle size and increase intake? Indeed, trials from many locations across the U.S. have shown that one can increase the intake of ground or pelleted hay over long hay by 10% to 40% when hay is the primary ration ingredient. Nonetheless, there are several reasons why grinding and/or pelleting hay is not more widely practiced at the farm level.

(1) It's important that ruminant animals receive some long fiber or "scratch factor" in their diets to maintain the health of the rumen tissue. This is especially important for animals to be retained in the herd for long periods of time, including lactating dairy cows, brood ewes, and beef cows. It's also known that fine-ground forage often leads to milk fat depression, an income-decreasing factor for the dairy farmer.

(2) Although intake is increased, digestibility suffers when forages are ground since they move more rapidly through the digestive system. Thus, the overall increase in digestible nutrient intake is not as great as one would expect.

(3) Forages are usually fed in some combination with concentrates and the positive effects of processing the forage are somewhat masked by the greater digestibility of the grains in the concentrate feeds.

(4) If the hay is of high quality, processing effects are minimized. Cows are effective at reducing particle size of long hay or forage, especially through the rumination or "cud-chewing" process. Rumination is important because, besides reducing particle size of forages, it increases the amount of saliva entering the rumen, which buffers the systems and promotes rumen health.

(5) Finally, the machinery, fuel, and labor costs of processing forages on the farm are seldom justified unless it is a necessity from a feeding system standpoint and/or the forage is of extremely poor quality.

Hay and Forage Feeding Fundamentals —Dairy

The major forages for the dairy cow diet are hay crop (either as dry hay or silage) and corn silage. High producing dairy cows will consume more than 4% of their body weight in dry matter intake per day. Given the nutrient demands for milk production, forages alone cannot meet the cow's nutrient requirements.

For the modern dairy cow diet, forages provide primarily energy and fiber, and secondarily, protein. However, given the nutrient demands for milk production, forages alone cannot meet the cow's nutrient requirements (see Figure 18-1). Therefore, supplemental grains (or concentrates) are provided to balance the diet.

The National Research Council (NRC) develops nutrient recommendations for all types of animals. In 2001, the latest edition of the *NRC Nutrient Requirements of Dairy Cattle, 7th Edition* was released. This very comprehensive guide utilizes a nutrient requirement determination based on the breed of cow, body weight, body condition score, stage of lactation, production level, milk fat concentration, milk protein concentration, and diet fed to the animal. Figures 18-1 and 18-5 are provided as examples only, and readers should consult the NRC's publication directly for more information.

The overall diet digestibility has a major influence on feed intake by cattle. The quality of the available forages dictates feed intake and the amount of concentrate needed to balance the diet. In general, plant fiber has lower digestibility than non-fibrous components (e.g., starch, sugars, or proteins). Therefore, forages with high fiber con-

FIGURE 18-1

Recommended Nutrient Content of Diets for Lactating Dairy Cattle

	Holstein 1,500 lbs BW, 90 days in milk, 3.5% fat, 3.0% protein			Jersey 1,000 lbs BW, 90 days in milk, 4.2% fat, 3.6% protein		
Breed						
Milk production, lbs.	55	77	99	55	77	88
Dry matter intake, lbs.	44.7	51.9	59.2	39.6	47.7	51.7
Daily weight change, lbs.	0.5	0.3	0.1	0	-0.2	-0.5
Energy						
NE, Mcal/day	27.9	34.8	41.8	27.7	35.6	39.5
NE, Mcal/lb	0.62	0.67	0.7	0.7	0.74	0.76
Protein						
MP, g/day	1862	2407	2954	1991	2639	2965
RDP, % of DM	9.5	9.7	9.8	9.7	9.8	9.7
RUP, % of DM	4.6	5.5	6.2	6.4	7.5	7.9
CP, % of DM (RDP + RUP)	14.1	15.2	16	16.1	17.3	17.6
Fiber						
NDF, Min. % of DM		25 - 33			25 - 33	
ADF, Min % of DM		17 - 21			17 - 21	
NFC Max % DM (Non-fibrous Carbohydrate)		36 - 44			36 - 44	
Minerals						
Ca, % of DM	0.62	0.61	0.67	0.57	0.57	0.63
P, % of DM	0.32	0.35	0.36	0.33	0.37	0.36
Mg, % of DM	0.18	0.19	0.2	0.18	0.19	0.2
Cl, % of DM	0.24	0.26	0.28	0.24	0.26	0.28
K, % of DM	1	1.04	1.06	1.02	1.03	1.04
Na, % of DM	0.22	0.23	0.22	0.2	0.2	0.2
S, % of DM	0.2	0.2	0.2	0.2	0.2	0.2
Co, mg/kg		0.11			0.11	
Cu, mg/kg		11			11	
I, mg/kg	0.6	0.5	0.44	0.44	0.4	0.34
Fe, mg/kg	12.3	15	17	14	16	17
Mn, mg/kg	14	14	13	12		
Se, mg/kg		0.3			0.3	
Zn, mg/kg	43	48	52	45	49	51
Vitamins						
A, IU/day		75,000			49,500	
D, IU/day		21,000			13,500	
E, IU/day		545			360	

Source: NRC.2001.Nutrient Requirements of Dairy Cattle, 7th edition

tent are less digestible than low-fiber feeds such as grains.

The major forages for the dairy cow diet are hay crop (either as dry hay or silage) and corn silage. When forages are of high quality such as corn silage, late bud alfalfa, and vegetative grasses, intake is not significantly restricted. In hay crop, the majority of the energy comes from digestion of the fiber, while in corn silage energy is generated from both the digestion of starch and fiber. The key to deriving forage energy is harvesting and storing high-quality forage.

FIGURE 18-2

Approximate nutrient density for varying grades of legumes and legume mixtures

Grade	Maturity	Definition	Physical Description	Typical Chemical Composition (%a) CP[d]	ADF[d]	NDF[d]	RFV[d]
1	Pre-bloom	Bud to first flower; elongation of stems to just before bloom	40% - 50% leavesb; green; >5% foreign material; no mold, musty odor, dust etc.	>19%	<31%	<40%	>140
2	Early	Early to mid-bloom;	35% - 45% leavesb; light green Initial to 50% bloom to green; >10% foreign material;	17-19%	31-35%	40-46%	124-140
3	Mid-bloom	Mid to full bloom; 50% or more in bloom	25% - 40% leavesb; yellow to green; >15% foreign material; no mold, musty odor, dust, etc.	13-16%	36-41%	47-51%	101-123
4	Full bloom	Full bloom	>30% leavesb; brown to green; >20% foreign material; no musty odor, etc.	<13%	>41%	>51%	<100

Sample GradeC Hay which contains more than a trace of injurious foreign material (toxic or noxious weeds and hardware) or that definitely has objectionable odor or is under cured, heat damaged, hot, wet, musty, moldy, caked, badly broken, badly weathered or stained, extremely overripe, dusty, which is definitely low quality or contains more than 20% foreign material or is more than 20% moisture.

a Chemical analysis expressed on dry matter basis. Chemical concentration based on research data from NC and NE States and Florida. Dry matter (moisture) concentration can affect market quality. Suggested moisture levels are grades 1 & 2 <14%, grade 3 <18%, grade 4<20%.

b Proportion by weight

c Slight evidence of any factor will lower a lot of hay by one grade

d CP=crude protein; ADF= acid detergent fiber; NDF= neutral detergent fiber; relative feed value is based on digestible dry matter intake.

Source: Rohweder et al. 1978. Journal of Animal Science 47:747.

High producing dairy cows will consume more than 4% of their body weight (BW) in dry matter intake (DMI) per day. For a 1,400 pound cow, that level of consumption equals 56 or more pounds of DM. In order to achieve that level of DMI, the forages must be of the highest quality. High-quality forages have greater digestibility and more nutrient density than low-quality forages as illustrated in Figures 18-2 and 18-3.

Mature forages restrict feed intake compared to immature forages, due to the lower digestibility of their fiber. For example, late bud alfalfa is normally 65% digestible, but full bloom alfalfa is normally less than 55% digestible. Work at Michigan State University (Oba and Allen, 1999) shows that high producing dairy cows (more than 65 lb/day of fat-corrected milk) consume 0.3 lb/day less DM and produce 0.35 lb/day less milk for every 1 percentage unit increase above 40% NDF content of alfalfa. So, if cows were fed alfalfa with 45% NDF, they would eat 1.5 lb/day DM and generate 1.75 lb/day milk less than cows eating 40% NDF alfalfa.

FIGURE 18-3

Grasses and Grass-Legume Mixtures (Hay Marketing Task Force)

Grade	Maturity	Definition	Physical Description	Typical Chemical Composition (%) CP[1]	ADF[1]	NDF[1]	RFV[2]
1	**Pre-head**	Late Vegetative to early boot; state at which stems are beginning to elongate to just before heading: 2 to 3 weeks regrowth	50% or more leaves; green; less than 5% foreign material; free of mold, musty odor, etc.	>18	<33	<55	124-140
2	**Early Head**	Boot to early head; stage between late boot where the inflorescences is just emerging until the state in which 1/2 inflorescence and anthesis: 4 to 6 weeks regrowth.	40% of more leaves; light green to green; less than 10% foreign material; free of mold, musty odor, etc.	13-18	33-38	55-60	101-123
3	**Head**	Head to Milk; Stage in which 1/2 or more of the florescence are in anthesis and the stage in which seeds are well formed but soft and immature: 7 to 9 weeks regrowth	Dough to seed: stage in which seeds are of dough-like consistency until stage when plants are normally harvested for seed: more than 10 weeks regrowth	8-12	39-41	61-65	83-100
4	**Post Head**	Dough to seed: stage in which seeds are of dough-like consistency until stage when plants are normally harvested for seed: more than 10 weeks regrowth	20% or more leaves brown to green; less than20% foreign material' slightly musty odor, dusty, etc.	< 8	> 41	> 65	< 83

[1] Chemical analyses expressed on dry matter basis. CP= crude protein: ADF = Acid detergent fiber; NDF = Neutral detergent fiber

[2] RFV= Relative Feed Value. RFV= (34.8 + 2.56 ADF-.0491 ADF) x (5.48 + 1.22 NDF) x .025

Source: Rohweder et al. 1978. Journal of Animal Science 47:747.

In lactating dairy cow rations, high-quality forages are more cost effective because they have a greater nutrient density than low-quality forages. There is approximately 0.09 Mcal more energy and 0.08 pounds more CP in one pound of late bud alfalfa compared to full bloom alfalfa. The energy and protein difference equals approximately 0.15 pounds of soybean meal. When one considers that there is really no cost difference to produce late bud alfalfa compared to full bloom alfalfa, the feed savings for an average cow fed a diet of 50% alfalfa is approximately four lbs of soybean meal or over $0.50 per cow per day based on current market prices. (This calculation includes 1.5 pounds of extra late bud alfalfa consumed by the cow compared to the full bloom alfalfa.) The main point to remember is that high-quality forages are required to both maximize production and minimize feed costs.

Which Forage? Alfalfa, Grass or Corn Silage

The correct answer to this question is a combination of these forages. The selection of forage for feeding to dairy cattle depends on a number of factors: quality, cost, and availability. In Wisconsin, alfalfa is the dominant forage fed, but in the Northeast, corn silage is the predominant forage. The difference is due to land availability, growing conditions, and markets. Even if one forage is predominantly used, almost all diets use a combination of two or more forages. The use of multiple forages in the diet spreads the risk of producing poor-quality forage, improves crop rotations, and allows for better diet formulations to maximize production.

But even with top management, forages vary more in quality than most grain crops. Therefore, to make the best use of high-quality forage, good forage quality testing is essential.

Balancing and Formulating Rations for the Milking Herd

The first consideration in any dairy feeding program is to determine the nutrient needs for body maintenance, growth, pregnancy or reproduction, and milk production. Recommended nutrient content of total diets for lactating cows as adapted from NRC tables are shown in Figure 18-1. Note requirements are presented on the basis of cow weight, milk fat percentage, and milk production, and are considered as the recommended nutrient content of the total ration.

Here in capsule form is a rundown of the nutrients required by dairy cattle, and how forages fit the bill:

Energy – In most dairy rations, forage, whether hay, grass or corn silage, is a primary source of energy. Measures of energy available to the animal include TDN and NEL. The most important factor affecting the energy value of forage is digestibility. And, growth stage at the time of harvest is the major determinant of digestibility as well as intake. Early cut forages are generally high in digestibility and intake, but the digestibility and intake values decline rapidly with maturity.

Lack of energy is the most common limiting factor for the high producing cow. Thus, for hay to make the maximum contribution in the dairy ration, it must be harvested early and managed to preserve as much energy as possible prior to feeding.

Protein – Proteins are essential for growth, repair of old tissue, and milk production. It is equally as important in the dairy cow ration as is energy. A ration short in protein will not allow efficient use of energy in the ration. In terms of ration-balancing protein, measurements include crude protein (CP), soluble protein (SP), rumen degradable protein (RDP), rumen undegradable protein (RUP), metabolizable protein (MP) and content of the two major limiting amino acids, lysine (LYS) and methionine (MET). Ruminant nutritionists are continuously refining the use of various protein fractions in ration balancing.

Metabolizable protein, LYS, and MET are not normally reported on forage analyses. Use of these terms is limited strictly to formulation of the diet using linear programming software. The RDP of the diet is digested and converted to bacterial protein in the rumen of the cow. The bacterial protein, along with the RUP of the diet, passes to the small intestine where it is digested and absorbed for use by the animal. The amount of digested bacterial protein and RUP absorbed by the animal is the MP generated by the diet. Bacterial protein has an amino acid (AA) profile that closely matches the AA profile of milk protein. The goal in formulating a dairy ration is to maximize bacterial protein production and supplement RUP sources that complement the bacterial protein to provide the optimal AA profile for maximum milk production. Lysine and MET are the limiting AA for milk production, and RUP sources are often selected to provide these AA at the correct ratio for optimal milk synthesis. Amino acid requirements increase proportionately with milk production, so higher producing cows require more RUP.

Legumes are a major source of protein in dairy rations with many lots of early cut alfalfa hay crop containing in excess of 20% CP. While the CP content of grass hays can be affected significantly by both nitrogen fertilization and early cutting, most lots of grass hays are much lower in the nutrient than legumes. The protein in high moisture silages is normally more soluble than dry hay, and therefore, may be utilized differently in the diet. Corn silage is a low protein feedstuff, but when fed at high levels, contributes a considerable amount of protein to the diet.

Fiber – Fiber is the most important nutrient component in ruminant rations for promoting health and maximum production in dairy cows. Hay provides a large amount of "scratch" or "roughage" factor, which is critical for proper rumen function.

For modern feeding programs, fiber is measured as neutral detergent fiber (NDF) and acid detergent fiber (ADF). The NDF content of the diet is the best indicator of intake, while ADF is a better indicator of forage digestibility.

Particle size in forages is also important. Diets containing large amounts of long forage (i.e., long hay or coarse chopped silage) promote sorting of the diet, which limits intake and causes metabolic problems associated with ruminal acidosis. Diets containing large amounts of too finely chopped or ground forage do not provide enough "scratch" factor to promote

FIGURE 18-4

Particle size recommendations for chopped forage and TMR diets

Screen	Pore size	Particle Size	Corn Silage	Haylage	TMR
Upper Sieve	.75''	> .75''	3% - 8%	10% - 20%	2% - 8%
Middle Sieve	.31''	.31'' - .75''	45% - 65%	45% - 65%	30% - 50%
Lower Sieve	.05'' *	.07'' - .31''	30% - 40%	30% - 40%	30% - 50%
Bottom Pan	-	< .07''	< 5%	< 5%	< 20%

*Pores are square, so the largest opening is the diagonal, which is .07 inches. This is the reason the largest particles that can pass through the Lower Sieve are.07 inches in length

Source: Heinrichs, J and P. Kononoff. Evaluating particle size of forages and TMRs using the New Penn State Forage Particle Separator. Penn State Cooperative Extension Publication Das 02-42.

FIGURE 18-5

Recommended Nutrient Content of Diets for Replacement Heifers

Breed	Holstein Heifer *Targeted to calf at 24 months, with a mature BW of 1500 lbs.*		
Age	**6 months**	**12 months**	**18 months** (Includes 90 day gestation)
Dry matter intake, lbs.	11.4	15.6	24.9
Energy			
ME, Mcal/day	10.6	16.2	20.3
ME, Mcal/lb	0.93	1.03	0.82
Protein			
MP, g/day	415	550	635
RDP, % of DM	9.3	9.4	8.6
RUP, % of DM	3.4	2.9	0.8
CP, % of DM (RDP + RUP)	12.7	12.3	9.4
Fiber			
NDF, Min. % of DM		30 - 33	
ADF, Min % of DM		20 - 21	
NFC Max % DM (Non-fibrous Carbohydrate)		34 - 38	
Minerals			
Ca, % of DM	0.41	0.41	0.37
P, % of DM	0.28	0.23	0.18
Mg, % of DM	0.11	0.11	0.08
Cl, % of DM	0.11	0.12	0.1
K, % of DM	0.47	0.48	0.46
Na, % of DM	0.08	0.08	0.07
S, % of DM		0.2	
Co, mg/kg		0.11	
Cu, mg/kg	10	10	9
I, mg/kg	0.27	0.3	0.3
Fe, mg/kg	43	31	13
Mn, mg/kg	22	20	14
Se, mg/kg	0.3		
Zn, mg/kg	32	27	18
Vitamins			
A, IU/day	16,000	24,000	36,000
D, IU/day	6,000	9,000	13,500
E, IU/day	160	240	360

Source: NRC.2001.Nutrient Requirements of Dairy Cattle, 7th edition

proper rumination, which also leads to metabolic issues. Penn State University provides a breakdown on proper particle distribution for chopped forages and total mixed ration (TMR) dairy diets based on the use of their Penn State Forage Particle Separator (see Figure 18-4). Recommendations for theoretical length of cut (TLC) for silages are ⅜" to ½" for hay crop silage and ⅜" to ¾" for corn silage (Jones et al., 2004). The TLC for corn silage is dependent on the use of kernel processing. If corn silage is kernel processed, then TLC should be ⅝" to ¾" to provide greater "chew/scratch" factor in the finished product to the cow.

Minerals – Well-fertilized forages are good sources of the mineral elements needed for dairy cows. Forages and other foodstuffs vary considerably in mineral content, but most of the requirements for the macro-minerals, Ca, P, K, S, and Mg, and the micro-minerals, Co, Mn, Zn, Fe, and Se, may be provided from the leafy forages consumed by dairy cows. High producing cows, however, will require extra supplements of most macro- and micro-minerals.

Next to salt, the total ration should be balanced for a Ca to P ratio no wider than 2:1. Avoid over-supplementation of minerals, especially P. Phosphorus (P) is considered an environmental pollutant from manure, and most states have regulations on the amount of P from manure that can be applied to fields to prevent runoff into fresh water rivers and lakes. Thus, a mineral analysis on forages is desirable for most accurate feed programming.

Vitamins – Vitamins A, D, E, and K are needed by cattle of all ages. And the most important sources to dairy cows are green leafy forages. Freshly harvested legume-grass silages are dependable sources of carotene, precursor of vitamin A. But carotene losses are continuous once forage is stored.

Forages with considerable exposure to sunlight, such as sun-cured hay, provide extra needed vitamin D, when fed to cows in liberal amounts. However, cattle fed solely legume-grass silages while in total confinement during the winter may require vitamin D supplementation.

Dairy cows must have vitamin E to maintain normal health. Normally, there are more than adequate amounts in green forage to supply the needs of dairy cows. But during storage, especially with silages that undergo heating during early fermentation, there are major losses of vitamin E. Vitamin assays are not normally included in a forage analysis and needed vitamins are best supplied through supplementation.

Building Rations for the Milking Herd

Building a ration for the milking herd is a complicated process and depends on many factors including the kind, quality, and availability of various forages and feedstuffs, and the relative cost of feed ingredients. Thus, check with local authorities for help in developing a sound feeding program for your herd. Today's nutritional consultants will use computer software programs to formulate rations to meet the nutrient requirements of the individual animals within a dairy herd

Total Mixed Rations (TMR): The TMR Concept of Feeding

The TMR concept of feeding dairy cows began in the late 1960's, and the use of the TMR for feeding dairy cattle has increased to the point where more than 60% of the U.S. dairy herds are fed in this manner. However, there are regions of the country where component feeding is still practiced to a large degree. Both types of feeding management can be used to produce large amounts of milk in dairy herds.

In brief, the three key principles in the TMR concept include: (1) mixing the feedstuffs to eliminate preference for individual ration ingredients, (2) balancing for nutrient content, and (3) offering free choice.
Chopped or ground hay can be included in a total mixed ration. But, high-quality hay at the rate of five to six pounds per head per day can also be fed to advantage in addition to feeds supplied through the total mixed ration.

Balancing and Formulating Rations for Heifers and Young Stock

Recommended nutrient content of diets for dairy heifers is shown in Figure 18-5.

High-quality hay or hay crop silage is a part of most growing heifer rations with or without corn silage. Usually, however, unless the hay is of exceptional quality, some grain should be fed in addition to hay.

An important thing to consider in developing heifers is to keep them growing and not allow them to become fat. A moderate- or high-forage ration during heifer development may allow greater feed capacity when the heifers come into milk production. Bringing heifers into production early in life can also cut the per head cost of replacing dairy cows. However, it is also equally important to make sure these heifers are grown out well when they are bred.

Hay also forms an important part of the diet of dairy young stock, and young calves should have access to hay at an early age. Most dairy farmers will offer hay to their calves by one to two weeks of age. Adequate hay intake significantly contributes to the development of the rumen. And, hay feeding of older calves and heifers aids the continued development of the rumen and provides an economical source of nutrients.

CHAPTER 19

Hay and Dairy-Herd Health

The goal of every feeding program is to maximize milk production by meeting the cow's nutrient requirements. However, this goal should never come ahead of maintaining the health of the animal. Proper rumen function is essential to maintaining and improving the cow's overall health. It is estimated that 60% to 80% of the production, health, and reproduction problems in dairy herds is associated in some manner with nutrition. Optimizing the use of forages in the diet goes a long way to maintaining the rumen and overall health of the animals in a dairy herd.

Too Little Fiber

One of the common challenges in formulating diets for high producing dairy cows is providing adequate amounts of fiber (i.e., NDF) to maintain rumen function and health. The problems associated with low fiber intakes are acidosis (both acute and subacute), variable intakes, displaced abomasums, low milk fat, and laminitis. If intake is normal, the minimum NDF requirement is 25% to 33% of DMI depending on the content of the diet. As nutritionists, we like to have at least 85% of the total NDF coming from forage sources. The forage NDF is what makes a cow ruminate (i.e., chew a cud), promotes rumen motility (i.e., movement), provides buffering capacity in the rumen, and slows passage of grains and concentrates for better digestion.

It is estimated that 60%-80% of the production, health, and reproduction problems in dairy herds is associated in some manner with nutrition. Optimizing the use of forages in the diet goes a long way to maintaining the rumen and overall health of the animals in a dairy herd.

Forage NDF alone does not ensure adequate rumination by a dairy cow. Particle size of forages plays a major role in the consumption, regurgitation, and cud chewing activity. Forages that are chopped too finely or mixed too long in TMR mixer have less "chew" factor, which may increase the likelihood of pH dropping in the rumen and occurrence of acidosis. Theoretical length of cut (TLC) for silages should be a minimum of ⅜" for the fiber to be effective. Longer chop lengths are appropriate up to ¾". Long hay is still the standard against which all other forages are measured in terms of "chew" factor.

Too Much Fiber

On the other end of the spectrum, too much fiber in the diet can also cause problems. Early lactation dairy cows require large amounts of energy for optimal milk production. There are two ways that there can be too much fiber. First, there can be too much NDF in the forages used to formulate the ration. When forage quality is limited, NDF content of forages increases. The increased NDF decreases energy density in the forage because the fiber in mature forages is less digestible. As a result, more grains have to be added to the diet to provide energy, which lowers the amount of total forage in the diet and reduces the "chew" factor for the total diet.

Second, the diet can be formulated to contain too much NDF. The forage NDF fills up the rumen, limiting intake, which limits overall energy intake, and thus, limits milk production. Further, diets with too much forage NDF are more likely to be sorted by the cow, and this can lead to pH drops and acidosis.

Forage Quality Paradox

In the last five years, a forage quality paradox has emerged within the dairy industry. That paradox is the use of straw or mature grass hay in lactating dairy cow diets. Why would any nutritionist use poor-quality forage for a high producing animal with energy limitation issues? As noted above, efforts to provide energy-dense rations have led to diets with too little fiber or "chew" factor, which can cause rumen function problems. As a result, there has been a movement to use a small amount (½ to 1 lb) of straw or mature grass hay in diets as a source of "chew" factor. The coarse nature of the straw, chopped at the appropriate length (i.e., approximately 2") to prevent sorting, provides "chew" factor and promotes mat formation in the rumen. The small amount of straw does not limit intake. The flip side issue increasing straw usage is that the straw market, which was driven by straw as bedding material, has seen a dramatic rise in prices with a ton of straw now selling for upwards of $150. Mature grass hay is acceptable for the same purpose, but variations in the quality of grass hay make it less appealing.

Additionally, straw has become a part of far-off and close-up dry cow rations. Fat cow syndrome is a serious condition where cows accumulate excess body condition (i.e., fat). This accumulation can often occur during the dry period where the traditional forage has been energy-rich corn silage. New low-energy-density, far-off, dry cow rations have been created with anywhere from 7% to 20% of the diet DM as straw. The straw is essentially used as filler, diluting the energy concentration of the ration. The low energy diet meets the dry cow's requirements while maintaining body condition. In close-up (two to three weeks pre-calving) rations, straw has been included as 2% to 7% of diet DM. This inclusion level allows more energy density while keeping the rumen full, which helps to prevent several metabolic disorders over the calving period including displaced abomasums and milk fever. Again, mature grass hay would be an acceptable solution if the quality were kept consistent. The difficulty with grass hay is the relatively high levels of potassium in grass compared to straw, and high potassium levels in close-up rations have been associated with increased incidence of milk fever.

Hay Feeding Problems

The quality of hay can present problems in heavy hay or hay crop diets. These types of problems are often associated with the presence of weeds or poisonous plants. Some forages produce alkaloids or other compounds that survive the drying, curing, or fermentation process, and negatively interact with the animal's metabolism.

A clear example of these types of anti-quality factors that can occur in forages is prussic or hydrocyanic acid. Prussic acid is produced when cyanogenic compounds are located in outer tissues of the plant and are acted upon by specific enzymes located in the plant's leaf tissue. Any event that disrupts the plant's cells and allows cyanogenic compounds and enzymes to mix will produce prussic acid. Plant cells can be broken up during cutting, crimping, wilting, and chopping, or by freezing, drought, trampling, and chewing. Figure 19-1 provides a partial list of the most common plants with cyanogenic potential.

Of the plants listed in Figure 19-1, Sudan grass, Johnsongrass, sorghums, and sorghum-Sudan grass hybrids are most commonly associated with prussic acid poisoning. Grain sorghums tend to be more toxic than forage sorghum or Sudan grass. Young, rapidly growing plants generally have high levels of prussic acid, especially new growth after a drought or a frost. Soil fertility can be associated with prussic acid issues as soils with high N and low P and K will elevate cyanogenic compound concentrations. Most prussic acid poisoning events are linked to plant regrowth following a drought-ending rain or the first autumn frost. Waiting at least seven days after a killing frost before grazing or harvesting should allow the cyanogenic compounds to dissipate. As fresh forages contain higher concentrations of prussic acid compared to silages and hays, avoid grazing new growth or regrowth in pastures.

FIGURE 19-1

Plants with Cyanogenic Potential

Apple	Forage Sorghum	Poison suckleya
Apricot	Grain Sorghum	Shattercane
Arrow Grass	Hydrangea	Sorghum-Sudan grass hybrids
Bird's-foot trefoil	Indiangrass	Sudan grass hybrids
Cherry	Johnsongrass	Velvet grass
Elderberry	Lima bean	Vetch seed
Flax	Peach	White Clover

Adapted from: Stoltenow and Lardy, 1998, Prussic Acid Poisoning. North Dakota State University Extension Publication V-1150.

FIGURE 19-2

Commonly found mycotoxins in the U.S.

Mycotoxin	Common Source	Levels known to cause animal health issues	Legal limit
Aflatoxin	Corn, peanuts, cottonseed	100 ppb	20 ppb in lactating dairy cattle, .5 ppb in milk
Deoxyneral(DON) or Vomitoxin	Corn, wheat, other small grains. Hay crop and corn silages	> 2.5 ppm	.5 ppm in wheat
T2 toxin	Corn, wheat, other small grains. Hay crop and corn silages	100 ppb	Unregulated
Zearalenone (ZEA)	Corn, wheat, other small grains. Hay crop and corn silages	400 ppb	Unregulated
Fumonisin (FB)	Corn and small grains	5 ppm	2-4 ppm for human food, 5 to 100 ppm for animal feeds depending on species
Ergot alkaloids, including fescue toxicity	Fescue pastures and hays	Direct effects proportional to diet	Unregulated
Ochratoxin (OTA)	Moldy forages and grains	?	Unregulated
PR toxin	Moldy forages and hays	?	Unregulated
Patulin	Moldy fruits, grains, and silages	?	Unregulated
Citrinin	Moldy forages and grains	?	Unregulated

Adapted from: Whitlow, L.W. and W.M. Hagler, Jr.,2007.Mycotoxins: a review of dairy concerns. Accessed at www.milkproduction.com.

While ensiling or drying will decrease prussic acid concentrations, high levels of prussic acid may remain if the standing crop had extremely high concentrations of prussic acid prior to harvest. If prussic acid is a possible concern, then have questionable hays and silages analyzed before feeding.

Another major problem that can occur with forages is the production and presence of mycotoxins. Mycotoxins are produced by molds during growth on plants prior to harvest, and these mycotoxins can have dramatic effects on the health of the animal (see Figure 19-2). Naturally-occurring mycotoxins have a much greater toxicity, normally due to the presence of multiple mycotoxins in one feedstuff.

Prevention of mycotoxins in feedstuffs is accomplished by minimizing stress on plants because mycotoxins are natural products of molds, and molds will colonize plants for a myriad of reasons. Molds are opportunistic organisms, and will colonize a plant whenever the plant is stressed. So, excessively dry or wet conditions, or any physical damage to plants caused by weather or insect infestation, will promote the colonization by fungi or molds and the production of mycotoxins. Also, mold growth during wilting, drying, curing, ensiling, and storage is an opportunity for mycotoxin production.

Treatment of mycotoxins normally occurs at feed out or during diet preparation. Binders are the most common treatment option, and the types of mycotoxin binders on the market include absorbent materials such as complex indigestible carbohydrates (glucomannans or mannanoligiosaccharides) or clays (bentonites and others).

CHAPTER 20

Hay Feeding Fundamentals – Beef, Sheep and Horses

High quality hay and pasture forms the backbone of a sound nutritional management program for horses. Hay for horses must be high in quality, which means the hay should be early cut, leafy, free of must, mold and dust, and relatively free of foreign material such as weeds and stubble.

With all production aspects considered, the beef cattle, sheep and horse industries probably rely on forages to provide at least three-quarters of their total feed needs. This exceeds the levels used by other classes of farm livestock.

Forage quality has been extensively discussed throughout the preceding chapters of this book. It is unfortunate in many beef cattle and sheep enterprises that forage quality has received little emphasis. However, as production costs have increased and market share has decreased due to the rapid rise of poultry consumption over the last decades, there has been an increasing push for improving forage quality to improve bottom line economics. The old idea that cattle and sheep are useful as "scavengers" for utilizing low-quality feeds has been replaced with the goal of improving quality forage production leading to greater animal productivity per unit land area. Today's emphasis is on maximum return per acre of land, whether as dollars or pounds of animal weight.

BEEF OPERATIONS

Cow-Calf

The key to maximizing efficiency and profits in the cow-calf enterprise is to match feed quantity and quality with the nutritional demands of the cow and calf. The five major production phases required throughout the year in the beef cow are indicated in Figure 20-1. The desirable length of time for each production phase is listed in the figure and is based on another important key to cow-calf profitability: a calf from each cow every 12 months. Meeting that goal is largely dependent on providing sufficient nutrients to the cow at proper times.

The relative feed demand indicated in the figure is a ranking of the quantity of nutrients required for the five production phases and should be considered in planning the feeding program. For example, in the case of hay, it's obvious that the best quality forage should be used in phase 1, when the cow's demands are at their peak. If we consider the relative forage quality (RFQ) index described previously, then the hay for beef cows, calves and stockers would have a value of 115 to 150, which corresponds to good to very good forage quality.

The time of year that you enter a given phase of the production cycle is also critical in feed management, and relates primarily to the choice for season of calving. Generally, calves should be born about 45 days before the best pasture season within your geographic area. Beef cows should reach peak milk production 60 days after calving, so calving a month or so prior to the pasture season means that cows will be grazing lush forage when milk production potential is highest and calves will be vigorous and rapidly growing to take advantage of the increased milk flow.

Fall calving may be justified in some situations, but one must recognize the need to harvest increased quantities of forage for winter feeding. The reason for this can be seen in Figure 20-2. Note that a 1,200-pound-dry, mature beef cow requires 13.8 pounds of TDN daily to meet her energy needs. However, once the cow calves, TDN requirements rise to 16.7 pounds daily at peak production, a 21% increase in energy needs. Under a fall calving schedule, a cow would likely calve

FIGURE 20-1

Production Phases in the Cow-Calf Enterprise

No.	Production Phase From:	To:	Time (days)	Body Functions1	Relative Feed Demands
1	Calving →	Start of Breeding	60	M, L, WG, RRT	1
2	Start of Breeding →	End of Breeding	60	M, L, C	2
3	End of Breeding →	Weaning	85	M, L	3
4	Weaning →	Pre-Calving (2 mo.)	100	M	5
5	Pre-Calving (2 mo.) →	Calving	60	M, RFG	4

Abbreviations for necessary body functions within the cow are: M = maintenance; L = lactation; WG = weight gain; RT = repair reproductive tract; C = conception; RFG = rapid fetal growth.

when little, if any, pasture would be available. In hay terms, this cow would require about 27.8 pounds of average quality alfalfa daily to meet her energy needs. The spring calving cow would likely be dry at this same time period and would require about 23.1 pounds of the same hay.

Producers with special markets or special management systems may find fall calving profitable, but must carefully

FIGURE 20-2

Selected Nutrient Requirements of Beef Cattle[a]

Body	Daily	Daily	Net Wt.							
Gain	Energy	DMb	Total Protein		TDN[b]		(Mcal/lb)			
Lbs.	Lbs.	Lbs.	%	lb./day	%	lb./day	NE_M	NE_G	Calcium	Phosphorus
Medium frame steer calves										
400	2.0	11.0	12.7%	1.41	67.5%	7.4	0.70	0.44	0.56%	0.26%
-	2.5	11.0	14.2%	1.56	73.5%	8.1	0.79	0.51	0.68%	0.30%
600	2.5	14.9	11.4%	1.69	73.5%	11.0	0.79	0.51	0.46%	0.26%
-	3.0	13.5	12.9%	1.73	85.0%	11.5	0.95	0.64	0.57%	0.29%
800	2.5	18.5	9.8%	1.81	73.5%	13.6	0.79	0.51	0.35%	0.21%
-	3.0	16.8	10.8%	1.81	85.0%	14.3	0.95	0.64	0.42%	0.25%
1000	2.0	22.0	8.4%	1.85	67.5%	14.9	0.70	0.44	0.25%	0.19%
-	2.5	21.9	8.8%	1.92	73.5%	16.1	0.79	0.51	0.27%	0.19%
Pregnant yearling heifers - last third of pregnancy										
800	1.4	17.4	8.8%	1.50	59.6%	10.4	0.59	0.33	0.33%	0.21%
950	1.4	19.8	8.4%	1.70	58.9%	11.7	0.58	0.32	0.29%	0.21%
Dry pregnant mature cows - middle third of pregnancy										
1000	0.0	18.1	7.0%	1.30	53.6%	8.8	0.42	–	0.18%	0.18%
1200	0.0	20.8	6.9%	1.40	52.9%	10.1	0.42	–	0.19%	0.19%
Cows nursing calves, first 3-4 months, avg. milking ability										
1000	0.0	20.2	9.6%	2.00	56.6%	11.5	0.55	–	0.28%	0.22%
1200	0.0	23.0	9.3%	2.10	55.5%	12.8	0.53	–	0.27%	0.22%
Cows nursing calves, first 3-4 months, superior milking ability										
1000	0.0	20.6	12.3%	2.50	67.0%	13.8	0.70	–	0.39%	0.27%
1200	0.0	23.8	11.5%	2.70	64.0%	15.2	0.65	–	0.36%	0.26%
Bulls, maintenance										
1800	0.0	28.9	6.8%	2.00	48.4%	14.0	0.41	–	0.21%	0.21%
2000	0.0	31.3	6.8%	2.10	48.4%	15.2	0.41	–	0.21%	0.20%

[a] From Nutrient Requirements of Beef Cattle, 1984, National Research Council. See this publication for a complete description of the nutrient requirements of beef cattle of various frame sizes, sexes, weights, and levels of production. [b] DM= dry matter; TDN - total digestible nutrients, NEM=net energy for maintenance and NEG= net energy for gain.

plan for the increased quality and quantity of winter forage required.

The environment under which cattle are managed should also be considered in planning the feeding program. Wintering programs in the upper Midwest and Northeast require up to 30% more energy per animal on a daily basis to overcome the cold stress.

Another sound nutritional management procedure relates to separating groups of cattle with similar size and nutrient requirements. Separating young, growing heifers from the mature cow herd has benefits as the larger, mature cows often crowd out the developing heifers at the feeder, limiting their growth. It's also desirable to provide a higher quality ration for the heifers to meet their greater protein and energy requirements for growth after calving. The diet needs to have a higher nutrient density as their body size limits their dry matter intake (DMI) throughout their first lactation (see Figure 20-3).

Special Considerations Affecting Reproduction

The importance of adequate energy intake in maintaining reproductive efficiency has been previously discussed. Several other nutrients, however, are also involved and should be carefully considered.

Phosphorus (P) is an extremely important mineral directly affecting conception rates. Research has clearly shown that first service beef cow conception rates were only 50% when phosphorus levels were below recommendations, while rates were over 70% when phosphorus was consumed at proper levels prior to the breeding season. While calcium levels in forage diets, especially legumes, are more than adequate, phosphorus may be marginal. A salt-mineral supplement, block fed, free-choice, should be adequate for most cattle.

In a similar vein, ***Vitamin A*** plays a key role in reproduction and is the vitamin most likely to be deficient in beef rations. The requirement for breeding cattle can be met by pro-vitamin A, or carotene, in feeds or by oral or injected vitamin A supplements. The conversion rate for carotene to vitamin A is one milligram of beta-carotene providing approximately 400 International Units (IU) of vitamin A in cattle. Most sun-cured high-quality hays are excellent sources of carotene. Pregnant cows and heifers require about 25,000 IU of vitamin A daily, and lactating cattle 40,000 IU. Under practical conditions, if high-quality hay is fed, these needs can be met by feeding only hay.

However, as a safeguard, after 3 to 4 months under a non-grazing regime, it is usually recommended that supplemental vitamin A either be injected or added to the ration. Consult a qualified veterinarian or nutritionist to determine regional recommendations.

Selenium (Se) is an extremely important mineral element that is functionally associated with vitamin E and can severely affect reproductive performance. Forage levels of selenium are often low, especially in the northeast region, and reflect deficient soil levels.

The federally-authorized limit for selenium supplementation in the total diet is 0.3 ppm, according to the Food and Drug Administration (FDA). Newborn calves maybe injected with a

FIGURE 20-3

Selected Nutrient Requirements of Two-Year-Old Heifers & Pregnant Replacement Heifers

Two-Year-Old Heifers (1200 lbs Mature Weight, 20 lbs peak milk)

Months[1]	Body Weight	Milk	DMI	TDN	ME	NE_M	CP	Ca	P	TDN	ME	NE_M	CP	Ca	P	Vitamins
	lbs	lbs/day		% of DM	Mcal/lb		- - - - - - % of DM - - - - - -			lbs	Mcal		- - - - - - lbs - - - - - -			1000's IU
1	972	12.30	22.9	60.4%	1.01	0.62	10.2%	0.30%	0.19%	13.8	23.1	14.2	2.34	0.069	0.044	41
2	984	14.80	23.8	61.4%	1.03	0.63	10.7%	0.32%	0.20%	14.6	24.5	15.0	2.55	0.076	0.048	42
3	998	13.30	24.5	59.2%	0.99	0.60	10.0%	0.29%	0.19%	14.5	24.3	14.7	2.44	0.071	0.047	43
4	1011	10.70	24.0	58.0%	0.97	0.58	9.4%	0.27%	0.18%	13.9	23.3	13.9	2.25	0.065	0.043	42
5	1025	8.00	23.4	56.8%	0.95	0.56	8.8%	0.25%	0.17%	13.3	22.2	13.1	2.05	0.059	0.040	41
6	1041	5.80	23.0	55.8%	0.93	0.55	8.3%	0.23%	0.16%	12.8	21.4	12.7	1.90	0.053	0.037	41
7	1059	-	21.5	48.9%	0.82	0.44	6.9%	0.19%	0.13%	10.5	17.6	9.5	1.48	0.041	0.028	27
8	1080	-	21.7	49.7%	0.83	0.45	7.1%	0.19%	0.13%	10.8	18.0	9.8	1.53	0.041	0.028	28
9	1106	-	22.0	51.0%	0.85	0.47	7.3%	0.19%	0.13%	11.2	18.7	10.3	1.61	0.042	0.029	28
10	1139	-	22.3	53.1%	0.89	0.50	7.8%	0.29%	0.17%	11.8	19.8	11.2	1.73	0.065	0.038	28
11	1180	-	22.8	55.9%	0.93	0.55	8.5%	0.29%	0.17%	12.7	21.2	12.5	1.93	0.066	0.039	29
12	1233	-	23.7	59.7%	1.00	0.61	9.4%	0.28%	0.17%	14.1	23.7	14.5	2.23	0.066	0.040	30

[1] Months Since Calving

Two-Year-Old Heifers (1200 lbs Mature Weight, 20 lbs peak milk)

Months[2]	Body Weight	Ave Daily Gain	DMI	TDN	ME	NE_M	CP	Ca	P	TDN	NE_M	CP	Ca	P	Vitamins
	lbs	lbs/day		% of DM	Mcal/lb		- - - - - - % of DM - - - - - -			lbs	Mcal	- - - - - - lbs - - - - - -			1000's IU
1	750	0.93	19.3	50.5%	0.46	0.21	7.2%	0.23%	0.18%	9.7	8.9	1.39	0.044	0.035	25
2	779	0.97	19.8	50.5%	0.46	0.21	7.2%	0.23%	0.18%	10.0	9.1	1.42	0.046	0.036	25
3	809	1.03	20.3	50.7%	0.46	0.21	7.2%	0.22%	0.18%	10.3	9.3	1.46	0.046	0.036	26
4	842	1.12	20.9	50.9%	0.47	0.22	7.2%	0.22%	0.17%	10.6	9.8	1.51	0.046	0.036	27
5	878	1.25	21.5	51.4%	0.48	0.23	7.2%	0.22%	0.17%	11.6	10.3	1.57	0.047	0.037	27
6	918	1.44	22.2	52.3%	0.49	0.24	7.3%	0.21%	0.17%	11.6	10.9	1.67	0.047	0.038	28
7	966	1.69	23.0	53.8%	0.51	0.26	7.5%	0.31%	0.23%	12.4	11.7	1.81	0.071	0.053	29
8	1022	2.01	23.7	56.2%	0.55	0.30	7.9%	0.31%	0.22%	13.3	13.0	2.02	0.073	0.053	30
9	1089	2.42	24.4	59.9%	0.61	0.35	8.5%	0.30%	0.22%	14.6	14.9	2.35	0.073	0.054	31

[2] Months since conception

Source: Gadberry, S., Beef Cattle Nutrition Series, Part 3: Nutrient Requirement Tables. MP 391, University of Arkansas & USDA.

selenium-vitamin E product at birth to further reduce the incidence of nutritional muscular dystrophy (commonly called white muscle disease). The disease can reach disastrous proportions in cattle herds (or sheep flocks) fed unsupplemented, low selenium feedstuffs.

Hay Feeding Systems

The advent of large hay packages (round bales and stacks) has sparked considerable interest in developing feeding systems which minimize waste and nutrient losses. Aspects of storing large hay packages have been discussed in a previous chapter and will receive minimal attention here. Certainly, maintaining feed quality starts at harvest and is further affected by storage conditions and feeding methods.

Minimizing big package hay losses generally involves some combination of bale protection and limiting cow access. Due to performance and environmental issues, leaving bales where they were made and allowing cows open access for fall or winter grazing has become a very limited practice.

Studies on bale losses during outdoor feeding of beef cattle have shown large amounts of material being wasted when cows have open access to hay (See Figures 20-4 and 20-5). Without racks, losses can be as high as 45% of the hay offered. The most important considerations when feeding hay outside are to control access and keep hay off the ground.

FIGURE 20-4

Hay wastage by cows when hay was fed with and without racks

Bale type	% of hay wasted
Square bale in rack	7%
Large round bale in rack	9%
Large round bale without rack	45%

Source: Mader et al., Management to Minimize Hay Waste, BCH-7310 - Beef Cattle Handbook

FIGURE 20-5

Hay wastage by cows on pasture under controlled-feeding situations

Feeding system	Hay / feeding (lbs/cow)	Hay refused/wasted %	Hay required over rack feeding
Rack feeding	-	5%	-
Non-rack feeding			
1-day supply	20	11	12
2-day supply	40	25	33
4 day supply	80	31	45

Source: Mader et al., Management to Minimize Hay Waste, BCH-7310 - Beef Cattle Handbook

Beef Bulls

The goal for beef bull development programs is to support average daily gains of 2.5 pounds from weaning to 14 months of age, 1.75 to 2.25 pounds from 15 months to 3 yrs of age, and maintain weight and condition in the mature bull. In addition to age, weight, and body condition, it's important to provide nutrients for the bull's activity during the breeding season.

Forages fit well with the nutritional demands of the beef bull. An all-hay or pasture diet of average quality will support approximately 1.5 pounds of average daily gain (ADG). Above this level, supplemental feed in the form of grains will be needed to meet growth goals. Specific nutrient needs are listed in Figure 20-6, outlining selected nutrient requirements for beef bulls. However, a common recommendation is 20 pounds of a good-quality, mixed hay with grain levels based on the variables described above.

The mineral and vitamin considerations outlined for the cow herd are also of importance for the breeding bull. The National Research Council (NRC, 1996) also points out that zinc is required for sperm production and may be low in some forages. Trace-mineral salt blocks will likely meet any given deficiency.

One management detail that requires more attention is separating the bull from the cow herd except during a restricted (60- to 75-day) breeding season. Even during the breeding season, if a mature bull is exposed to more than 35 cows per bull in a breeding pasture, or if the breeding pasture is particularly large and rough, a bull should receive some additional supplement to maintain libido and fertility.

The value of at least limited amounts of long hay in the beef cattle feedlot diet should not be overlooked. All-concentrate rations have often led to digestive disturbances and costly liver abscesses. Even a limited amount of 2 pounds long or chopped hay per head daily tends to minimize such problems and promote desirable rumen function.

FIGURE 20-6

Selected nutrient requirements for beef bulls

Bull calves up to 12 months of age (2000 lbs Mature Weight)

Body Weight	Avg. Daily Gain	DMI	TDN	NE_M	NE_G	CP	Ca	P	TDN	NE_M	NE_G	CP	Ca	P	Vitamin A
------- lbs- ------		lbs/day	% of DM	Mcal/lb		------- % of DM -------			lbs	Mcal		------- lbs -------			1000's IU
300	2.5	8.7	68	0.71	0.43	18.5%	0.95%	0.43%	5.9	3.53	2.30	1.61	0.830	0.037	9
400	2.5	10.7	68	0.71	0.43	16.2%	0.76%	0.35%	7.3	4.38	2.85	1.73	0.081	0.037	11
500	2.5	12.7	68	0.71	0.43	14.5%	0.63%	0.29%	8.6	5.18	3.37	1.84	0.080	0.037	13
600	2.5	14.5	68	0.71	0.43	13.4%	0.54%	0.26%	9.9	5.93	3.87	1.95	0.078	0.038	15
700	2.5	16.3	68	0.71	0.43	12.7%	0.47%	0.24%	11.1	6.66	4.34	2.07	0.077	0.039	16
800	2.5	18.1	68	0.71	0.43	11.8%	0.42%	0.22%	12.3	7.36	4.80	2.13	0.076	0.039	18
900	2.5	19.7	68	0.71	0.43	10.9%	0.38%	0.20%	14.1	8.04	5.24	2.14	0.075	0.040	20

Yearling and Breeding Bulls (2000 lbs Mature Weight)

Body Weight	Avg. Daily Gain	DMI	TDN	NE_M	NE_G	CP	Ca	P	TDN	NE_M	NE_G	CP	Ca	P	Vitamin A
------- lbs- ------		lbs/day	% of DM	Mcal/lb		------- % of DM -------			lbs	Mcal		------- lbs -------			1000's IU
1000	1.73	25.2	60	0.61	0.35	7.5%	0.25%	0.14%	15.1	8.71	3.79	1.89	0.062	0.036	25
1100	1.73	27.0.	60	0.61	0.35	7.1%	0.23%	0.14%	16.2	9.35	4.07	1.92	0.062	0.037	27
1200	1.73	28.9	60	0.61	0.35	6.8%	0.22%	0.13%	17.3	9.98	4.34	1.96	0.063	0.039	29
1300	1.73	30.7	60	0.61	0.35	6.5%	0.21%	0.13%	18.4	10.60	4.61	2.00	0.063	0.040	31
1400	1.73	32.4	60	0.61	0.35	6.3%	0.20%	0.13%	19.4	11.20	4.88	2.03	0.064	0.041	32
1500	1.73	34.1	60	0.61	0.35	6.0%	0.19%	0.13%	20.5	11.80	5.14	2.06	0.065	0.043	34
1600	1.73	35.8	60	0.61	0.35	5.8%	0.18%	0.12%	21.5	12.38	5.39	2.09	0.066	0.044	36
1700	1.73	37.5	60	0.61	0.35	5.7%	0.18%	0.12%	22.5	12.96	5.64	2.13	0.066	0.046	38
1800	1.73	39.1	60	0.61	0.35	5.5%	0.17%	0.12%	23.5	13.53	5.89	2.16	0.067	0.047	39
1900	1.73	40.8	60	0.61	0.35	5.4%	0.17%	0.12%	24.5	14.90	6.13	2.19	0.068	0.049	41
2000	0	37.2	46	0.39	0.00	5.6%	0.17%	0.13%	17.1	14.64	0.00	2.07	0.062	0.047	37

Adapted from Gadberry, S. Beef Cattle Nutrition Series, Part 3: Nutrient Requirement Tables. MP 391, University of Arkansas & USDA.

Growing Heifers and Steers

Selecting and developing replacement females is one of the most important factors contributing to the process of a beef herd – commercial or purebred. In many ways, more careful nutritional management is required for replacements than for feedlot heifers. Energy intake in the replacement heifer must be controlled so that they grow, but not fatten. Over-feeding will lead to over-conditioning, fatty infiltration of the udder, and low reproductive and lactation efficiency.

The goal for heifer replacements is to calve the first time at 24 months of age, which provides great efficiency. This goal requires breeding at 14 months of age with an appropriate weight dependent upon the breed. Typically, British breed heifers should weigh 650 pounds, medium size exotic breeds 750 pounds and large exotic breeds 800 pounds. Figure 20-7 provides target weights and gains for replacement heifers as recommended by the NRC (1996). Producers should plan ahead to meet these targets.

Steer and heifer calves to be finished for market will often be placed on a grower program before being placed on a high energy finishing ration. Forages typically comprise a high proportion of these grower rations as one is attempting to develop skeletal size and muscle in the animal without promoting excess fat accumulation. Nutrient requirements for growing heifers and steers are provided in Figure 20-8.

Finishing Steers and Heifers

At present, the marketing system for fed beef in the U.S. is based on the attainment of choice quality grade, a reflection of the amount of intramuscular fat or marbling dispersed within the lean meat. Reaching this level of marbling typically requires that cattle be fed a relatively high energy ration, at least for a 60- to 90-day finishing period. This has led to a heavy use of cereal grains in finishing diets with limited use of hay or other roughages because of their relatively low energy density.

Currently, however, there is considerable interest in reducing the fat content of beef and utilizing a higher proportion of forage in the ration of market cattle. The degree to which the industry continues to adopt these strategies (e.g., "grass-fed") is largely dependent on future consumer preferences and economic factors.

FIGURE 20-7

Target ages, weights, and gains for beef replacement Heifers (1996 Beef Cattle NRC)

Development Stage	Age(Months)	Target weight(lbs)	% Maturity	Target gain (lbs/day)
Weaning period	8	450	41%	1.75
Post-weaning to breeding	9	500	45%	1.25
Breeding to calving	14	684	62%	0.8
Calving to rebreeding	23	880	80%	0.4
Second breeding season	27	927	84%	0.4
Second calving	36	1012	94%	0.2

Adapted from: NRC, 1996. Nutrient Requirement of Beef Cattle, 7th Revised Edition. Washington, D.C.

FIGURE 20-8

Selected nutrient requirements for beef heifers and steers

Heifer calves and steers (1,200 lbs Mature or Finishing Weight)

Body Weight	Avg. Daily Gain	DMI	TDN	NE_M	NE_G	CP	Ca	P	TDN	NE_M	NE_G	CP	Ca	P	Vitamin A
------- lbs- ------		lbs/day	% of DM	Mcal/lb		------- % of DM -------			lbs	Mcal		------- lbs -------			1000's IU
300	2	8.6	68%	0.7	0.42	16.20%	0.80%	0.36%	5.8	3.07	1.8	1.4	0.069	0.031	9
400	2	10.7	68%	0.7	0.42	14.10%	0.63%	0.30%	7.3	3.81	2.23	1.51	0.068	0.032	11
500	2	12.6	68%	0.7	0.42	12.90%	0.53%	0.26%	8.6	4.5	2.64	1.63	0.067	0.033	13
600	2	14.4	68%	0.7	0.42	12.10%	0.46%	0.23%	9.8	5.16	3.03	1.74	0.067	0.034	14
700	2	16.3	68%	0.7	0.42	11.30%	0.41%	0.21%	11.1	5.79	3.4	1.85	0.067	0.035	16

Yearling Heifers and Steers (1,200 lbs Mature or Finishing Weight)

Body Weight	Avg. Daily Gain	DMI	TDN	NE_M	NE_G	CP	Ca	P	TDN	NE_M	NE_G	CP	Ca	P	Vitamin A
------- lbs- ------		lbs/day	% of DM	Mcal/lb		------- % of DM -------			lbs	Mcal		------- lbs -------			1000's IU
840	2	22.1	60%	0.61	0.35	8.80%	0.30%	0.16%	13.3	6.64	3.9	1.94	0.071	0.035	22
900	2	23.3	60%	0.61	0.35	8.40%	0.28%	0.16%	14	6.99	4.11	1.96	0.065	0.037	23
960	2	24.4	60%	0.61	0.35	8.10%	0.27%	0.15%	14.6	7.34	4.31	1.98	0.066	0.037	24

Adapted from Gadberry, S., Beef Cattle Nutrition Series, Part 3: Nutrient Requirement Tables. MP 391, University of Arkansas & USDA.

Finishing diets from 750 pounds to market weight will usually consist of free-choice concentrate and a limit feeding of 2 pounds of hay per head daily and should result in daily gains of 2.5 to 3.0 pounds. Various combinations of corn silage and corn grain are also popular for grower and finisher programs. Good quality corn silage, properly supplemented with protein and minerals, should allow cattle to gain around 2 pounds daily and 40% corn silage 60% grain rations should allow cattle to gain at near their genetic potential.

The type of farming operation also affects the choice of feeding system. Smaller farmer-feeder operators are perhaps in the best position to utilize higher forage programs. The typical, large-capacity feedlot must handle a tremendous volume of feedstuffs and from a material handling standpoint the more energy-dense cereal grains are more manageable than roughages.

Typically these operators must also make maximum use of their facilities, requiring high rates of cattle growth, thus increasing the number of cattle marketed per unit time. Farmer-feeders, on the other hand, may feed only one group of cattle per year and may be more concerned with utilizing those feeds that can best be produced on their particular land resource.

The value of at least limited amounts of long hay in the feedlot diet should not be overlooked. All-concentrate rations have often led to digestive disturbances and costly liver abscesses. Even a limited amount of 2 pounds long or chopped hay per head daily tends to minimize such problems and promote desirable rumen function.

Long hay for starting calves on feed is also desirable under most conditions, as stressed calves will tend to consume hay readily where grain might be refused or lead to digestive upset. Once calves are adjusted to the feedlot situation, concentrate can be slowly increased to the desired level.

The total ration should be balanced so that the ratio of calcium to phosphorus is two to one. Beef cattle rations, particularly if they contain high-quality forage, do not lack calcium. Phosphorus is the mineral most likely to be lacking, and if a concentrate mixture or protein supplement is fed, there should also be a source of calcium, phosphorus, and salt added to the concentrate or total ration.

High grain diets are usually deficient in both calcium and phosphorus. Some feeders offer free-choice mineral mixes in addition to those added into the ration. A common mixture is equal parts of trace-mineralized salt, ground limestone, and dicalcium phosphate.

Potassium levels should be kept at 0.8% to 1% of the total ration and is most critical on high grain diets. Vitamins A and D are present in green forages or can be supplemented into the diet or injected intra-muscularly. Most feedlot rations also contain a feed additive, ionophore, which improves the efficiency of feed utilization on both forage and grain diets.

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Ewes

Forage utilization with sheep is similar to beef cattle and much of the discussion in the previous sections is applicable to sheep. Specific nutrient requirements published by the National Research Council (NRC) are presented in Figure 20-9.

Perhaps the most striking difference between the requirements of ewes and cows is the need for rations of higher protein content. Note that 154-pound ewes nursing twin lambs require almost 15% total protein. This indicates the need to provide high-quality legume forage at this and other periods of high nutrient demand. Always match the forage quality to the needs of the ewe. Save the poorest quality forage for the early gestation period when demands are lowest. Such planning can drastically cut the requirement for grain or protein supplementation of forage during the latter part of gestation and during lactation.

The nutrient requirements provided in Figure 20-9 should be considered minimums, and stress factors such as very hot or cold temperatures, parasites, large amounts of required exercise, etc., can markedly increase the feed requirements of sheep as well as any other types of livestock.

Note that specific nutrient requirements are listed in the table for the period just prior to and during the early part of the breeding season. This is the “flushing” season and proper nutrition can increase lambing percentages by 30% or more. Grain may be used during this flushing period, but many sheep farmers use high-quality hay.

Although flushing is critical, too much grain at any time during the year can cause the ewe to become too fat and actually decrease efficiency of production through lower fertility, higher feed cost, and more lambing problems. Ewes in moderate flesh or condition will respond more to flushing than will fat ewes. Therefore, ewes should be maintained in moderate flesh and thrifty condition for best results from flushing before the breeding season.

The principal determinant of profitability in the sheep enterprise is the number of lambs that can be marketed per ewe

FIGURE 20-9

Selected Nutrient Requirements of Sheep[a]

Body Weight (lbs)	Daily Gain (lbs)	Daily DM[b] (lbs)	Total Protein %	TDN[b] lbs/day	TDN[b] %	DE[b] lbs/day	DE[b] Mcal/day	Calcium %	Phosphorus %
Ewe Maintenance									
110	0.02	2.2	9.5%	0.21	55%	1.2	2.4	0.20%	0.18%
154	0.02	2.6	9.6%	0.25	57%	1.5	2.9	0.20%	0.20%
Ewes - Flushing - 2 wks. Pre-breeding and first 3 wks. Breeding									
110	0.22	3.5	9.4%	0.33	60%	2.1	4.1	0.33%	0.16%
154	0.22	4	9.0%	0.36	58%	2.3	4.7	0.32%	0.18%
Ewes - No lactating - First 15 wks. Gestation									
110	0.07	2.6	9.6%	0.25	58%	1.5	3.0	0.24%	0.18%
154	0.07	3.1	9.4%	0.29	55%	1.7	3.4	0.25%	0.21%
Ewes - Last 4 wks. Gestation (130-150% of Lambing) or last 4-6 wks. Lactation - Single Lamb									
110	.40 (.10)	3.5	10.9%	0.38	60%	2.1	4.1	0.37%	0.30%
154	.40 (.10)	4	10.5%	0.42	58%	2.3	4.7	0.34%	0.31%
Ewes - Last 4 wks. Gestation (180-225% Lambing)									
110	0.5	3.7	11.6%	0.43	65%	2.4	4.8	0.36%	0.20%
154	0.5	4.2	11.2%	0.47	67%	2.8	5.4	0.40%	0.24%
Ewes - First 6-8 wks. Lactation - Single Lamb or Last 4-6 wks. Lactation - Twin Lambs									
110	-0.06 (0.2)	4.6	1460.0%	0.67	65%	3.0	6.0	0.42%	0.29%
154	-0.06 (0.2)	5.5	13.3%	0.73	65%	3.6	7.2	0.37%	0.28%
Ewes - First 6-8 wks. Lactation twin Lambs									
110	-0.13	5.3	16.2%	0.86	64%	3.4	6.9	0.44%	0.30%
154	-0.13	6.2	14.8%	0.92	65%	4.0	8.0	0.39%	0.29%
Replacement Ewe Lambs									
66	0.5	2.6	15.8%	0.41	65%	1.7	3.4	0.53%	0.22%
88	0.4	3.1	12.6%	0.39	65%	2.0	4.0	0.42%	0.19%
110	0.26	3.3	9.1%	0.3	58%	1.9	3.9	0.32%	0.19%
Replacement Ram Lambs									
88	0.73	4	13.5%	0.54	63%	2.5	5.0	0.43%	0.21%
132	0.7	5.3	10.9%	0.58	64%	3.4	6.7	0.35%	0.18%
176	0.64	6.2	9.5%	0.59	63%	3.9	7.8	0.30%	0.16%
Finishing Lambs - 4 to 7 months old									
66	0.65	2.9	14.5%	0.42	72%	2.1	4.1	0.51%	0.25%
88	0.6	3.5	11.7%	0.41	77%	2.1	5.4	0.41%	0.21%
110	0.45	3.5	10.0%	0.35	77%	2.7	5.4	0.35%	0.19%
Early Weaned Lambs - Rapid Growth Potential									
22	0.55	1.3	26.9%	0.35	65%	1.1	2.1	0.82%	0.37%
44	0.66	2.6	17.3%	0.45	77%	2.0	4.0	0.54%	0.24%
66	0.72	3.1	15.5%	0.48	77%	2.4	4.8	0.51%	0.24%

[a] From Nutrient Requirements of Sheep, 1985, NRC, Washington, D.C. See this publication for a more complete listing of sheep nutrient requirements.
[b] DM= dry matter; TDN = total digestible nutrients; DE= digestible Energy

maintained. This has led to considerable emphasis on increasing lambing percentages and encouraging ewes to lamb more than once per year. Breeds of sheep are now available that are capable of consistently producing three or more lambs per lambing. The nutrient requirements provided in Figure 20-9 are based on an average of 1.5 lambs per ewe. Cornell University research suggests that the NRC recommendation be adjusted up

215% for ewes with triplets and 240% for ewes with quads.

Finishing Lambs

The primary change in the type of lambs fed for market in recent years is the genetic ability to gain three-quarters of a pound or more per day, at least on high energy diets. However, the choice of feeding system will depend on the management system used and relative forage/concentrate prices. Lambs can be successfully finished on a wide range of diets, typically consisting of various combinations of high-quality alfalfa hay and concentrates.

However, lambs are highly susceptible to enterotoxemia or over-eating disease and additional care is needed as the percentage concentrate in the diet increases. A feed additive, ionophore, is recommended to improve feed energy utilization and decrease the incidence of coccidiosis.

Rams

Rams, like beef bulls, should be maintained in a thrifty, but not fat condition. Rams should not require any additional grain if high-quality hay is available, except approximately three weeks before the breeding season and for the same length of time after the breeding season. Under most conditions, one pound of a simple grain mixture will keep rams in good shape before and after breeding.

Hay and plenty of exercise are two requirements to keep rams thrifty when they are not with the ewe flock.

HORSES

High-quality hay and pasture forms the backbone of a sound nutritional management program for horses. Hay for horses must be high in quality, which means the hay should be early cut, leafy, free of must, mold and dust, relatively free of foreign material such as weeds and stubble, and have a good green color. As with pasture, this type of hay is usually rich in energy, protein, materials and vitamins, and is readily consumed by horses with little wastage.

Horse owners prefer grass hay for horses. However, free choice feeding studies have shown that horses prefer legume hays over grass hay, and within legumes, clover hay over alfalfa hay.

Respiratory or digestive disturbances frequently associated with feeding hay were found to be more related to dust and mold than to species or mixtures.

Quality concerns in hay focus on endophytes in fescue. A study at the University of Kentucky conducted through the foaling season revealed that 40% of the mares grazing highly endophytic (72%), tall fescue exhibited reproductive abnormalities.

Outside of fescue toxicosis, red clovers often cause health issues in horses. Red clover has a natural tendency to become dusty, and can harbor a disease called black-path that causes the slobbering syndrome (excess salivation) in horses. Hay should be cut regularly and promptly to avoid buildup of black-path.

Foals

The growing foal needs a high-quality, low-fiber diet that will not limit intake. The total rations for growing foals after weaning should contain about 14% total protein depending on the type of horse and the amount of growth that is occurring. Supplemental protein after one year of age is not necessary with good-quality legume-grass forages.

Mares

High quality forage can be fed as the main part of the ration to pregnant mares. However, more attention must be paid to providing proper energy, protein, minerals, and vitamins during the last trimester of pregnancy. Have the forage tested and meet any deficiencies with concentrates.

The lactating mare, like any other type of livestock, must receive more energy and more protein than the gestating or "dry" mare. By harvesting forage at an early stage of maturity so that fiber content will not restrict hay intake, all-forage diets may be consumed in amounts that will meet nutrient requirements. A relatively low (i.e., 13%) protein forage is needed to provide sufficient protein during lactation. Mineral and vitamin supplements should also be offered to the lactating mare. Again, monitor forage quality, intake, and supplement as required.

Mature Horses

In horses where mature weight is being maintained and there is no pregnancy, lactation, or heavy work being done, average quality forages are usually sufficient for both energy and protein needs. Careful attention should be paid to body condition with horses of any age or activity to prevent their becoming too fat or too thin. Thin horses should be carefully examined for parasites, a common cause of poor body condition.

The growing foal needs a high-quality, low-fiber diet that will not limit intake. The total rations for growing foals after weaning should contain about 14% total protein depending on the type of horse and the amount of growth that is occurring. Supplemental protein after one year of age is not necessary with good-quality legume-grass forages.

FIGURE 20-10

Daily Energy, Protein, Mineral & Vitamin Requirements for Different Production Stages for a horse with a mature weight of 1,100lbs.

Class of horse Mcal/day	DEa lbs	CPa grams	Calcium grams	Phosphorus
Breeding Stallion	22	1.7	20	14
Broodmare				
Early pregnancy	17	1.4	20	14
8 mo. Pregnant	18.5	1.7	28	20
11 mo. Pregnant	21	2	36	26
Lactation				
1st- month	32	3.4	59	38
2nd- month	31	3.2	56	36
3rd-month	28	2.9	40	25
Working Horse				
Light exercise	20	1.5	30	18
Moderate exercise	23	1.7	35	21
Heavy exercise	27	1.9	40	29

Production State	Copper	Zinc	Magnesium	Potassium	Vitamin A	Vitamin D	Vitamin E
	grams				(IU)		
Maintenance	0.1	0.4	7.5	25	15,000	3,300	500
12 mo. Of age	0.08	0.32	5.4	17	14,500	5,600	642
Early Pregnancy	0.1	0.4	7.5	25	30,000	3,300	800
Lactation (3 mo.)	0.13	0.5	11	46	30,000	3,300	1,000
Moderate Exercise	0.12	0.5	12	32	22,500	3,300	900

FIGURE 20-11

Daily Energy, Protein & Macro-mineral Requirements for a growing horse with a mature weight of 1,100lbs.

Age (Weight/Growth)	DE[a] lbs	CP[a] grams	Calcium grams	Phosphorus
6 mo. (475 lbs, 2 lb/day)	15.5	1.5	39	22
12 mo. (700 lbs, 1 lb/day)	19	1.8	3.8	21
24 mo. (940 lbs, .4 lb/day)	19	1.7	3.7	20

[a] DE= digestible Energy, CP = Crude Protein
Adapted from: NRC, 2007. Nutrient Requirements of Horses, 6th Revised Edition. Washington, D. C.

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