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Harvest Management for Producing Alfalfa in South Dakota

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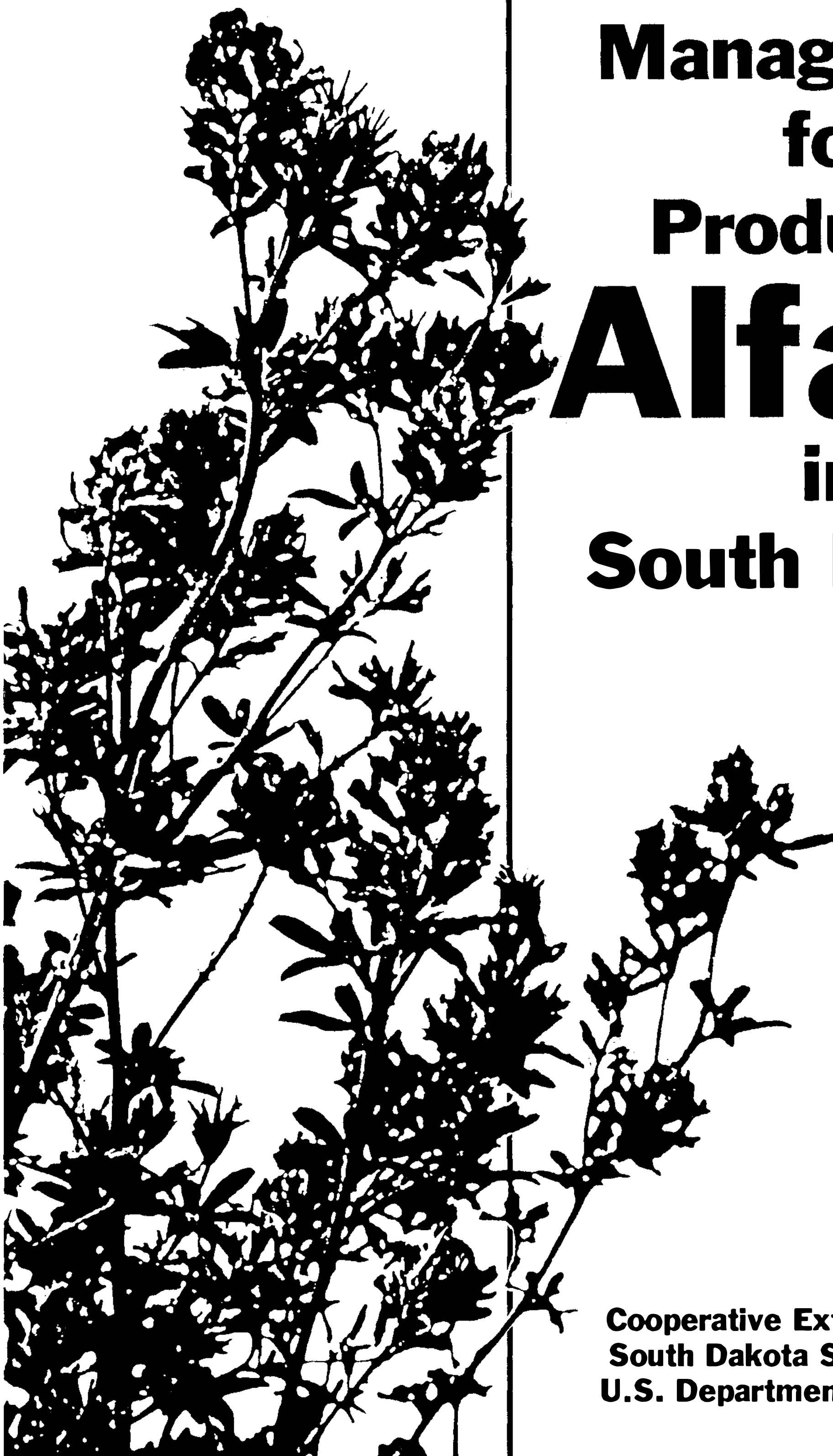

Cooperative Extension Service
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Harvest Management for Producing Alfalfa in South Dakota

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Harvest management affects yield, quality, and persistence of alfalfa. While producers may strive for high yield, excellent forage quality, and stand longevity, all of these goals are difficult to achieve with one system of harvest management.

Compromise among these three factors is often necessary. To determine which harvest management system is best for you, you need to understand how yield, quality, and persistence are influenced by plant maturity and harvest methods.

Optimizing Forage Yield, Quality, and Persistence

Forage Yield

Forage yield generally is greatest when the crop is harvested at the full-bloom stage of maturity. This typically allows two harvests per year in most of South Dakota. Harvesting at the bud stage of maturity results in lower forage yields compared to yields obtained at full bloom (Table 1). Thus, if high forage yield is the primary consideration in deciding when to harvest alfalfa, two cuttings at full bloom would be the harvest management to select.

Increases in forage yield also mean changes in composition of the forage. The amount of leaves in the forage declines from about 55% to about 40% of forage dry weight between the bud stage of growth and seed set. Because leaves are the most digestible part of the forage, fewer leaves results in large decreases in forage quality as alfalfa matures. Thus, management decisions based solely upon high yield may result in high yields of poor quality forage.

Table 1. Influence of plant maturity on forage yield of alfalfa.

	Kansas[a]		Wisconsin[b]	
Growth stage	Harvests	Yield	Harvests	Yield
	--No./yr--	--T/A--	--No./yr--	--T/A--
Bud	5	2.6	3	1.8
10% Bloom	4	3.2	3	2.4
100% Bloom	4	3.4	2	3.2
Seed	3	2.9	2	2.8

[a] Eight year average
[b] Five year average
Source: Adapted from Smith, 1975.

Forage Quality

Alfalfa is one product of the farming operation where quality has a major impact on how the harvested material will be used. The maturity stage at harvest and the techniques used during harvest and storage have major impacts on forage quality. Young, succulent growth produced prior to the bud stage has high quality, but it yields so little forage that harvesting often is not justified. Conversely, the high forage yields obtained at full bloom (Table 1) are of poor quality. Thus, a compromise between forage yield and quality must be made.

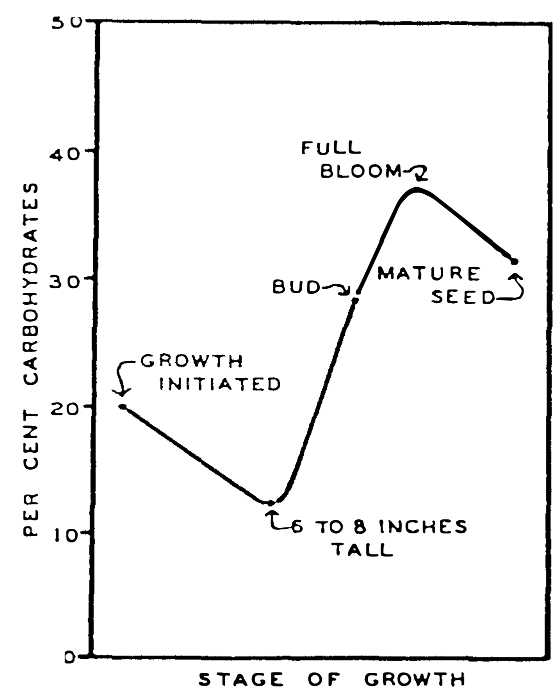
An approach useful in analyzing the trade-off between yield and quality is to express yield in terms of tons of digestible dry matter (DDM) produced per acre (Table 2). Although slightly lower forage yields are obtained when plants are harvested at late-bud or 10% bloom, yield of both DDM and protein are greater at these stages of growth than forage harvested twice per season

Root Nutrient Reserves

A knowledge of the root carbohydrate reserve cycle is essential for understanding how harvest management influences alfalfa yield and persistence. Carbohydrate reserves provide energy for initial growth in the spring, regrowth following harvest, and for many other physiological processes in the plant. Storage and utilization of root reserves follow a cyclic pattern, decreasing during the initiation of regrowth and then accumulating until plants reach full flower (Figure 1). Between full bloom and mature seed, the amount of carbohydrates may decrease as new shoots form at the crown of the plant. From the 1920s through the 1940s, it was commonly recommended to harvest at full bloom to ensure that root carbohydrate levels were maximized.

This cyclic pattern is always followed, so whether alfalfa is left unharvested, or is harvested one, two, three, or four times during a season, the amount of carbohydrates in the roots declines with the initiation of growth in the spring and after each cutting, and increases as the regrowth approaches flowering. Carbohydrates then accumulate in the root and crown tissue during autumn in response to decreasing temperatures and day length. These stored carbohydrates are the main source of energy during winter.

Figure 1. Changes in the amount of carbohydrates in alfalfa roots during growth.



Frequent harvests of immature alfalfa which prevents vegetative regrowth from developing enough to replenish reserves can result in reduced carbohydrate levels. This may be associated with stand decline and yield loss (Table 3). The negative effects of frequent cutting may be reduced if alfalfa is allowed to flower at least once annually to permit adequate storage of carbohydrates.

Harvest Schedules

Harvesting By Calendar Date

Cutting by calendar date, or using a fixed number of cuts per season with no particular attention paid to the maturity of the alfalfa, is one harvest management option. Since harvesting on a fixed interval does not account for the effect of environmental conditions and dormancy differences among varieties, the most satisfactory interval between cuttings will vary with location, climate, and season of the year.

A fixed system of cutting based on calendar date may allow easier scheduling of harvesting with other field activities. In South Dakota, cool, cloudy weather often delays flower development in the spring growth of alfalfa. For this reason, producers may decide to cut before June 1 regardless of stage of maturity to avoid the high probability of rainy weather in early June and potential delays in subsequent cuttings.

Harvesting By Maturity Stage

A harvest schedule based on plant maturity depends on the stage of plant development to indicate the proper time to cut and the number of cuttings possible in a season. Research from several states indicates that cutting according to stage of development is superior to cutting at fixed intervals in obtaining consistent forage yield and quality.

In areas of South Dakota in which three to four cuttings are common, it is advantageous to harvest at first flower. This stage is probably the best compromise to optimize forage yield and stand persistence. It is also a maturity stage that is easily recognized by producers. The disadvantage of relying on maturity stage as the sole criterion for making harvest management decisions is that cool weather or stress conditions such as drought may delay flowering, and consequently producers may not be able to take as many cuttings in a season as they had planned on if they delay harvest until a certain maturity stage is reached.

Table 2. Influence of maturity stage on yield of digestible dry matter (DDM) and crude protein of alfalfa.

Growth stage	Harvests	DDM	Crude protein
	--No./yr--	----------T/A----------	
Late Bud	4	2.36	0.82
10% Bloom	3	2.23	0.77
100% Bloom	2	2.05	0.59

Univ. of Missouri, 1970

at full bloom. The lower yield of DDM and protein at full bloom generally is associated with leaf loss and an increase in the amount of lignin in the stems.

Plant Persistence

Removal of leaves and stems during harvest is stressful for alfalfa plants. Renewed growth of leaf and stem tissue requires use of starch and protein stored in roots. The more frequent the harvest, the more stress that is placed upon the plants and the greater the likelihood of stand damage. When compared to plants harvested at first-flower or later, alfalfa harvested at early-bud yielded the same amount of forage in the first harvest year, but it yielded less in each of the three subsequent years (Table 3).

Table 3. Long-term forage yield of alfalfa as influenced by harvest management.

Growth Stage	Harvests	Total Yield Per Year 1	2	3	4
	--No./yr--	------------T/A---------------			
Early Bud	5	2.8	2.6	2.2	1.7
First Flower	4	3.1	3.6	2.6	3.6
50% Bloom	3	2.8	3.0	2.6	3.2

Univ. of Missouri, 1986

Yield reductions are much greater for disease-susceptible varieties than for those resistant to disease. In addition, low potassium fertility levels have been implicated in contributing to stand losses, particularly under intensive harvest regimes. Therefore, to have alfalfa successfully survive the additional stress imposed by frequent harvesting, you need to eliminate other factors such as insects, diseases, and inadequate plant nutrition.

Intensive Cutting Management

Before you implement a specific harvest management system, carefully consider the animal requirements for forage quality and forage nutrient yield, as well as variety winterhardiness and desired stand longevity.

The University of Minnesota conducted a study that investigated harvest management systems in detail. Previously recommended three-cut (June 1, July 15, and August 31) and four-cut systems (June 1, July 15, August 31, and October 15) served as controls for six other systems.

Results suggested that for consistently high-quality forage, a less winterhardy variety harvested four times by August 31 (system H) or September 15 (system E) provided maximum quantities of high-quality forage in the short term, with a potential for rapid decline in persistence (Table 4).

In contrast, a more winterhardy variety harvested in early June, mid-July, and late August (system A) would meet requirements for greater nutrient yield and long-term stand persistence.

Harvest systems having potential compromise among these factors (nutrient yield, forage quality, and persistence) were the four-cut systems E and F and three-cut system C. Quality of alfalfa for systems E, F, and G was generally superior to that for systems A, B, or C, whereas alfalfa persistence was not as adversely affected as that of alfalfa cut by systems D and H.

Table 4. Average forage yield and quality of alfalfa under different management systems at St. Paul, Minnesota.

Cutting Schedule[1]	Number of cuts	Forage Yield	Crude Protein	Relative Feed Value
		-T/A-	---%---	
A 2 ff + fb by Aug 31	3	4.9	20	140
B 2 ff + Sept 15	3	4.8	20	139
C 2 bud + Aug 31	3	4.4	21	141
D ff, 2 fb + Oct 15	4	5.4	21	148
E bud, ff, fb + Sept 15	4	4.4	21	162
F bud, ff, fb + Oct 15	4	5.0	20	150
G bud, ff, s + Oct 15	4	4.9	21	156
H 2 bud, ff + Aug 31	4	4.2	22	165

[1]Abbreviations of stage of maturity at harvest: b, bud; ff, first flower; fb, full bloom; and s, seed.
Source: Adapted from Brink and Marten, 1989.

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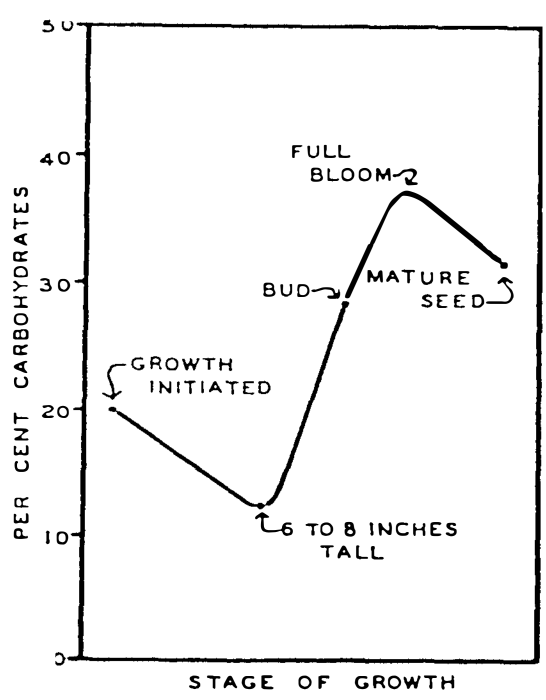

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Harvesting By Crown Shoot Development

Regrowth of alfalfa occurs from crown buds and axillary buds on stems. Crown buds are responsible for spring regrowth and are primarily formed during the previous fall. Additional crown buds develop in spring before initiation of regrowth. Because of the association between basal shoot development, alfalfa maturity, and carbohydrate reserves, basal shoot elongation has served as an indicator when the crop is ready to cut.

In South Dakota where winter-dormant varieties are grown, this method is not superior to cutting according to a fixed schedule or maturity stage because environmental factors influence new shoot elongation. Shoots often develop from the crown when prolonged dormancy induced by drought is broken or when canopy lodging exposes the crown to light. This method of harvest management is best-suited to the more arid regions of the U.S.

Management of the First Cutting

The timing of the first cutting in the spring is extremely important because it usually dictates the total number of cuttings made during the growing season, and it may influence the recovery of stands that have been damaged during winter. The first cutting of a stand that has suffered winter damage should be made at full flower. This allows accumulation of root carbohydrate reserves and healing of tissues injured during winter.

For healthy stands of alfalfa, harvesting at first flower provides optimum forage yield, quality, and restoration of high levels of root reserves. However, flexibility in first cutting management is required since:

- Unfavorable weather conditions may be present.
- Cutting at earlier stages may be necessary for alfalfa weevil control.
- If high quality forage supplies are limited, cutting at earlier stages may be desirable.
- Late spring frosts may destroy the growing points.

Fall Harvest Management

A long-standing recommendation is to avoid harvesting alfalfa during a 4- to 6-week period prior to the average date of the first killing frost in autumn. This period is typically from early September through mid-October for the north central states. The basis for this recommendation is that regrowth of alfalfa during autumn may prevent adequate replenishment of root reserves for winter survival. If an early killing frost occurs, however, the crop may be harvested irrespective of date. Harvest at the time of the killing frost should not promote damage to the stand because the plants will not have the opportunity to regrow.

Some researchers have concluded that the evidence supporting the "critical fall period" response may be overly simplistic. Environmental conditions, harvest management, stand age, alfalfa variety, and other factors interact to influence winter survival of alfalfa. The results of several investigations suggest that harvest of alfalfa during the critical fall period does not necessarily injure alfalfa stands or reduce yield in subsequent years, particularly when modern varieties with multiple pest resistance are used. Researchers in Minnesota concluded that concern for damage of alfalfa by harvest during the critical fall period may be minimized if stands existed on well-drained soils with adequate fertility, a modern winterhardy variety was used, and adequate insulation by snow cover occurred.

South Dakota Research

Since there are conflicting results from several states regarding fall harvest management of alfalfa, a study was conducted in South Dakota with the objective being to determine how late-season harvest date affects alfalfa yield components for the subsequent spring. A field experiment was established at Brookings, SD in May of 1989. Treatments included two (June 10 or August 10) or three (May 25, June 25, and August 10) cuts before a final harvest in late summer or autumn. The final harvest treatments included nine single cuts that began on August 20 and continued on about 10-day intervals until November. These harvest treatments were imposed in 1990 and 1991. Samples and data were collected to measure alfalfa yield components in late May of 1991 and 1992, after the previous year's harvest treatments.

Lowest alfalfa yield in spring was observed for the September 10 and 20 harvest treatments in 1991 and for the August 30 and September 10 treatments in 1992 (Figure 2). Yield for the September 10 treatment was 44 and 41% less than the control for the spring of 1991 and 1992, respectively. The August 20, October 20, and November 10 treatments had similar yields to the control in the spring of 1991 and the August 20 and November 10 treatments were similar to the control in 1992.

Figure 2. Alfalfa forage yield for spring growth of two years following 10 different late-season harvest treatments the previous year.

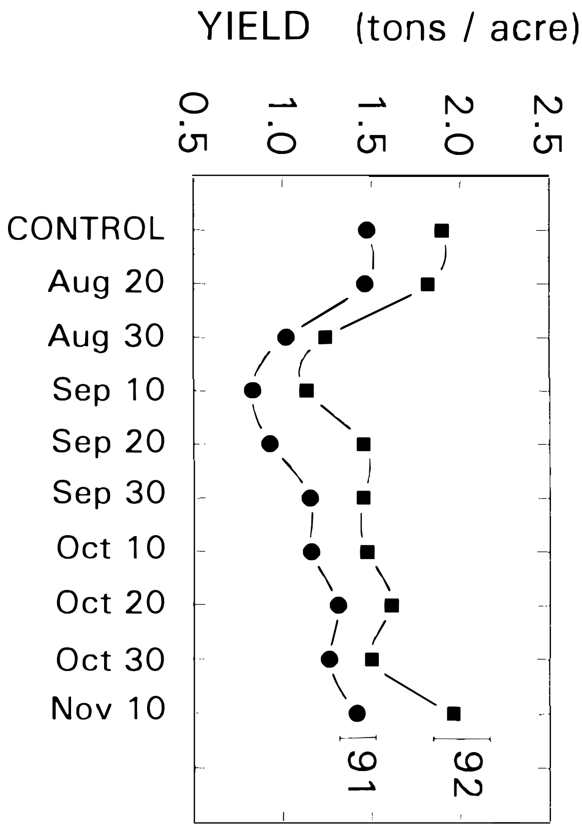
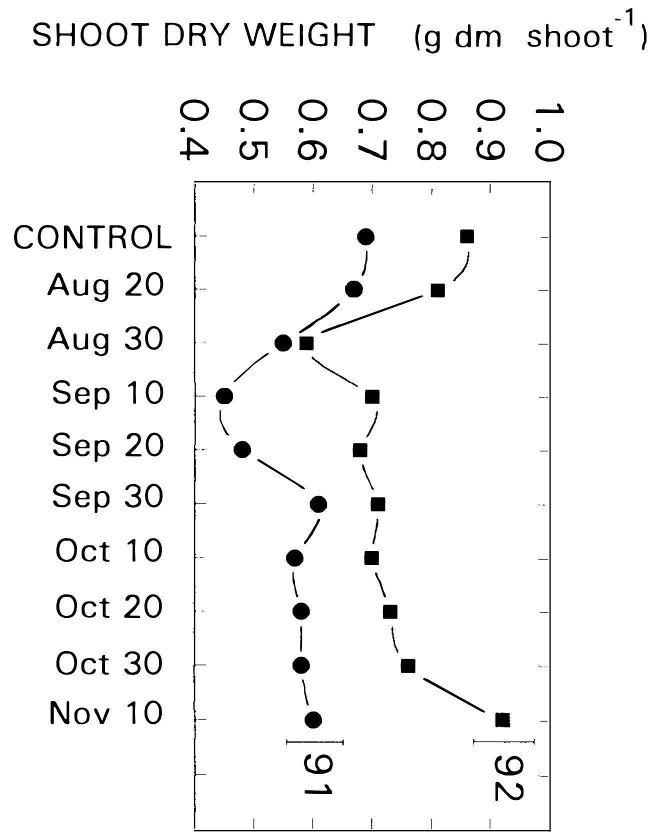


Figure 3. Alfalfa shoot dry weight for spring growth of two years following 10 different late-season harvest treatments the previous year.



The only alfalfa yield component clearly affected by late-season harvest date was shoot dry weight (Figure 3). Minimum shoot dry weight in spring was observed for the August 30 and the September 10 and 20 treatments in 1991 and for harvests from August 30 through October 10 in 1992. There were no consistent effects of cuts per growing season or late-season harvest on plant population density or shoot number per plant; however, there was a trend for the September 10 treatment to have the lowest number of shoots per plant in 1991.

These results are more consistent with traditional critical fall period recommendations than with observations of recent studies in Minnesota and Michigan. Late-season harvest did not result in increased plant mortality, suggesting that late-season harvest of alfalfa may be done periodically provided that producers are knowledgeable of the risks. Harvest may occur if warranted by yield, curing conditions, soil water, fertility, and variety. Increased plant stress will likely result for September-harvested stands, particularly if subsequent winter snow cover is absent. These alfalfa stands should be permitted a recovery period the following year.

Harvest Losses

The objective of hay-making is to cause a rapid moisture loss after cutting so the forage can be removed from the field with minimal losses from weathering and microbial degradation. The water content of an active growing forage plant is about 85-90%. Hay must be field-cured down to 20% moisture for safe storage of small bales and 18% moisture for large hay packages. To produce 1 ton of hay at 20% moisture requires the removal of about 7 tons of water from 8 tons of fresh forage.

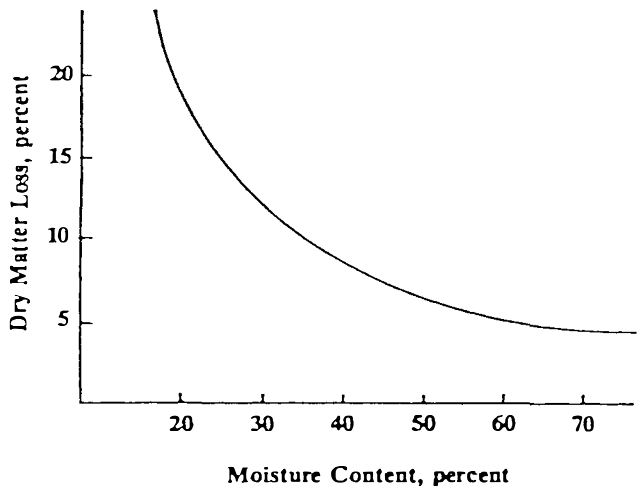


Figure 4. Losses in alfalfa as influenced by moisture content when raked.

Hay drying can be described as a two-phase process (fast and slow). The initial drying of forage is rapid with 75% of the water loss in the first 20% of the drying time. When forage is below 30% moisture, drying becomes very slow. The drying power of the air determines the speed of water release from the plant.

Losses of dry matter during curing cannot be eliminated. Field harvest losses increase as the moisture content of the forage decreases. During field drying, hay is subjected to various mechanical treatments to increase the rate of drying and produce a dry crop for storage. These treatments cause losses primarily due to leaf loss and shattering into pieces too small to be gathered mechanically.

Initial field losses occur during cutting and conditioning. Dry matter losses during cutting have been estimated to range from 1 to 6% and losses during mechanical conditioning range from 1 to 4%. Raking causes the greatest dry matter loss in the field and often ranges from 5 to 15%. Avoid raking if water content is less than 50%. Results of raking alfalfa hay at various moisture levels are shown in Figure 4. Baling losses have been estimated to range from 1 to 15%.

Weathering Losses

Rain is often blamed as being the main problem in producing high quality alfalfa hay. Rain during the curing process reduces hay yield, leaches soluble constituents, and increases shatter losses. Research from Kentucky indicated that rain-free and rain-damaged alfalfa hay had similar crude protein contents (Table 5). Hay cured without rain damage was about 6 percentage units lower in digestibility (IVDMD) than fresh herbage; however, rain damage increased the difference to 13 units. Hay cured without rain was only about 3% higher in NDF (neutral detergent fiber) than fresh herbage, but rain had large effects. The average NDF concentration of rain-damaged alfalfa was 54%, which was 8 units higher than undamaged hay. The fact that NDF was affected so dramatically indicates that forage intake potential would be greatly reduced in rain-damaged hay. Yield losses averaged 17% without and 23% with rain (Table 5).

This research reinforces the notion that if the goal of the grower is to produce high-quality hay, haymaking should be a high priority. Use weather forecasts to time harvests within a narrow window of no more than two or three days before or after the "ideal" maturity stage. There are many tasks that can be done in cool, cloudy, or even rainy weather, but haymaking is certainly not one of these.

Table 5. Forage quality and yields of alfalfa herbage and hay.

Type	Crude protein	IVDMD	NDF	Yield loss
	-------------------	----------%	-------------------	
Herbage	22.8	70.3	42.8	----
Hay-no rain	20.3	64.0	46.1	17.2
Hay-rain	20.2	57.4	53.9	22.8

Univ. of Kentucky, 1990

Chemical Aids to Haymaking

Drying Agents

Hay drying agents are chemicals applied to standing forage at cutting. They reduce field drying time by increasing the rate of water loss from cut alfalfa. These materials do not directly dry the hay. Rather, the chemicals break down the waxy layer called the cuticle on alfalfa stems, allowing moisture to evaporate faster.

The two most popular chemicals used as drying agents on alfalfa are potassium carbonate and sodium carbonate. Research indicates that potassium carbonate is the more effective of the two, but it also is the more expensive. In some cases, the two chemicals have been mixed together to reduce costs.

Drying agents are most effective during good drying conditions, which typically occur during the mid-summer period. They are less effective in the first cutting when drying conditions usually are not optimum.

Drying agents are applied to the alfalfa at cutting with spray equipment mounted on the cutting implement. A pushbar is used regularly to bend the plants forward so the spray solution can be applied uniformly to the stems and leaves. Application rates often call for as much as 30 to 50 gallons of water per acre with the drying agent. This requirement is a major reason why drying agents have not gained wider acceptance. Newer products are being developed that only require 15 to 30 gallons of water per acre for adequate application.

Preservatives
Preservatives differ from drying agents in that they do not hasten any of the drying processes. Instead, preservatives are used by growers wishing to store forage at relatively high moisture contents. Most of these products contain propionic acid or a mixture of propionic and acetic acid. These products act as fungicides to reduce heating and storage losses and to prevent mold.

Preservatives are best applied at the baler. These products are volatile and will be lost if applied long before baling. Recommended rates of propionic acid are about 1.0% for hay baled at 20-25% moisture, 1.5% at 25-30% moisture, and 2.0% for hay at 30-35% moisture. Prevention of mold is more difficult and cost of preservative becomes great when the hay contains more than 30% moisture.

The major drawback to using preservatives is that they are highly acidic. They can irritate skin and corrode equipment. Adding neutral, buffered compounds reduces the volatility and corrosiveness of the preservative and should enhance the use of acid preservatives.

Lactic-acid-forming and other biological products also are sold as hay preservatives. Research indicates that these products are less effective than propionic acid preservatives. These products usually can be used safely on hay between 20 and 25% moisture. There seems to be large biological differences between the bacterial strains contained in inoculant products. This is probably why research results with these products have been extremely variable.

Consider both drying agents and preservatives as "tools" in the overall haymaking operation. Weather conditions during haymaking, cost of application equipment and products, and the need to produce high quality hay determine whether using these products will be economically justified.

References

Brink, G.E., and G.C. Marten. 1989. Harvest management of alfalfa-nutrient yield vs. forage quality, and relationship to persistence. Journal of Production Agriculture. 2:32-36.

Collins, M. 1990. How much does rainfall affect the quality and yield of cut alfalfa? p. 29-31. In Proc. 20th National Alfalfa Symposium, Lincoln, Neb. 16-17 Feb., 1990. Certified Alfalfa Seed Council, Davis, Calif.

Heath, M.E., R.F Barnes, and D.S. Metcalfe. 1985. Forages: The science of grassland agriculture. Iowa State University Press, Ames, Iowa.

Hoveland, C.S. 1980. Crop quality, storage, and utilization. American Society of Agronomy, Madison, Wis.

Kephart, K.D., and E.K. Twidwell. 1993. Autumn harvest management effects on spring growth of two modern alfalfa cultivars. p. 104-107. In Proc. Forage and Grassland Conf., Des Moines, Iowa. 29-31 March, 1993. American Forage and Grassland Council, Georgetown, Texas.

Smith, D. 1975. Forage management in the north. Kendall/Hunt Publishing Co., Dubuque, Iowa.