R-571 (Revised)

NORTH DAKOTA STATE UNIVERSITY
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# ALFALFA MANAGEMENT in North Dakota

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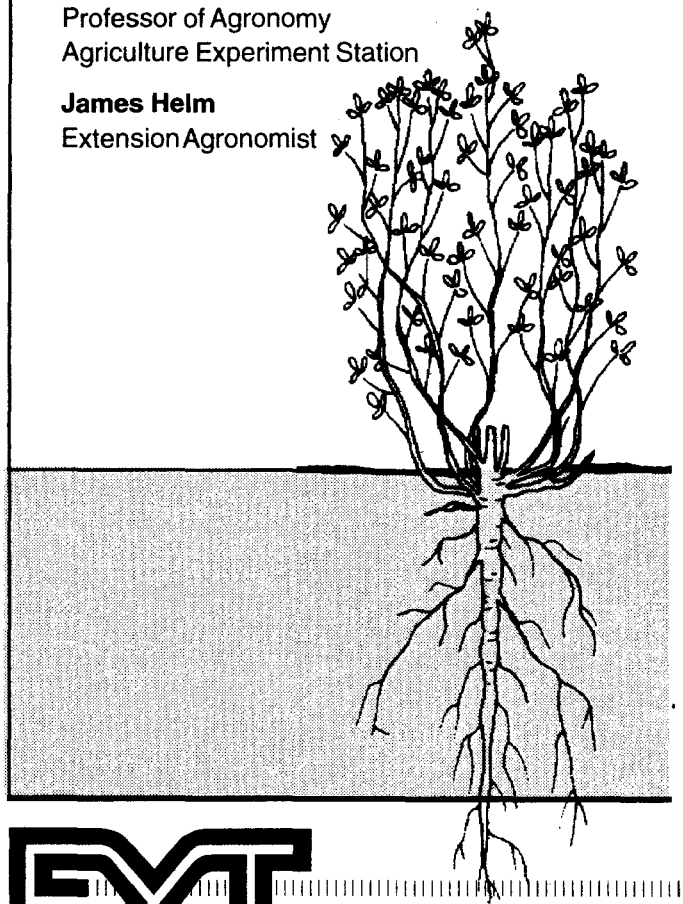

Alfalfa is the most widely grown perennial legume in North Dakota. Its primary use is for hay, but it is also used for pasture and haylage and as a green manure crop. The acreage harvested for hay (Table 1) held relatively constant from the mid 1950s to 1970. The acreage increased to nearly 2 million acres during the 1970s and is currently at about 1.7 million acres. During this same time period the acreage of native hay harvested has also decreased. Total hay acreage is influenced most by moisture, increasing during and after dry years and declining after wet years.

**Table 1. Acreage of alfalfa, tame grass and native hay harvested.**

| Year | Alfalfa | Tame grass & native hay | Total |
|---|---|---|---|
| 1960 | 1,261 | 2,626 | 3,887 |
| 1965 | 1,326 | 2,297 | 3,623 |
| 1970 | 1,500 | 2,056 | 3,556 |
| 1975 | 1,920 | 1,620 | 3,540 |
| 1980 | 1,200 | 1,300 | 2,500 |
| 1985 | 1,500 | 1,450 | 2,950 |
| 1990 | 1,400 | 2,100 | 3,500 |
| 1992 | 1,300 | 1,600 | 2,900 |
| 1993 | 1,700 | 1,250 | 2,950 |

The North Dakota Agricultural Statistics Service indicates that the average statewide alfalfa yield for the years 1988-1992 was about 1.8 tons/acre. The highest yields (Figure 1) were in eastern North Dakota and ranged from 1.6 to 2.1 tons/acre, compared with yields of 0.9 to 1.2 tons/acre for the remainder of the state. These yields are about 0.5 ton/acre less than the long-term average. In addition, the 25-year average forage

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NOVEMBER 1994

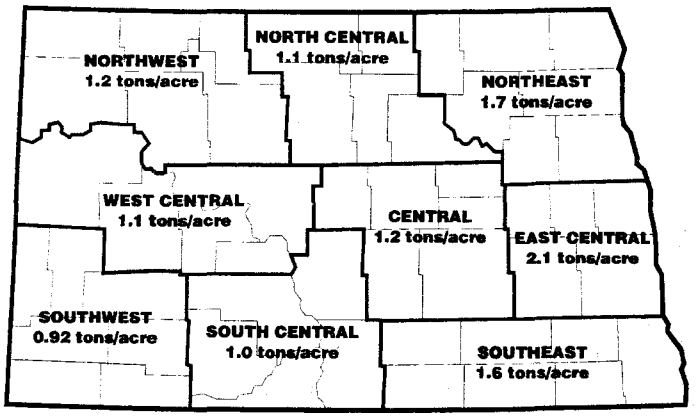


**Figure 1. Average yields of alfalfa for years 1988-92 by North Dakota crop reporting districts.**

yield at Fargo is 4.2 tons/acre, nearly 2.0 tons/acre more than the Cass County average. Several factors contributed to this disparity and indicate the potential for top-notch producers.

Alfalfa forage yields can be improved or maintained at high levels through the timely application of stand management principles and practices. Consideration should be given to rotation of stands on a regular basis, timeliness and frequency of forage harvesting, packaging and storage, fall management, and soil fertility. Information on individual varieties can be found in NDSU Extension Circular R-681, **"Alfalfa Variety Selection."**

## Stand Management

Alfalfa is a perennial crop which must store food reserves or carbohydrates (starches and sugars) in its crown and taproot for winter survival. Adequate food reserves are essential for development of cold resistance, for plant respiration or maintenance during the winter, and to initiate new growth in the spring and following each harvest. A knowledge of the carbohydrate storage pattern in alfalfa is fundamental to understanding the plant's response to various management systems.

Storage of carbohydrates follows a cyclic pattern throughout the growing season (Figure 2). Food reserves decrease in uncut alfalfa until about mid-May, corresponding with about 6 to 8 inches of new growth. As growth continues, the leaves manufacture carbohydrates in excess of normal growth and development needs, allowing storage of "food" in the crown and taproot. Food reserves in uncut alfalfa increase until full bloom in late June or early July, decrease until seed is mature in August, and increase until the first killing frost in the fall.

Alfalfa cut two or three times annually for hay has a similar cyclic pattern in stored food reserves—decreasing until new growth is 6 to 8 inches tall, then increasing until the next cutting or until the first killing frost (Figure 2). Note that with timely harvesting and/or grazing in the fall, food reserves are maintained at nearly the same level as in uncut alfalfa stands. With an adequate recovery period in early fall, allowing complete recovery of food reserves prior to forage harvest is not necessary. Therefore, maintenance of productive stands is possible even when the forage is removed early (bud to 10 percent bloom) in order to harvest high-quality hay. However, harvest during the fall storage of food reserves may lead to winter injury and reduced life of the stand.

## Age of Stand

The productive life of an alfalfa stand is related to the age of stand and the harvest and/or grazing management. Increasing age of stand, too many cuttings during the growing season, untimely fall harvesting, and overuse by grazing animals often result in one or all of the following:

- REDUCED YIELDS
- LIMITED ROOT GROWTH
- INCREASED WINTERKILL AND/OR INJURY
- THINNING OF STANDS
- GRASS AND WEED INVASION
- INCREASED DISEASE SUSCEPTIBILITY

Alfalfa requires approximately 6 inches (plus or minus 1 inch) of water to produce a ton of forage. To produce greater than normal yields for your area, additional moisture must be available through above-normal precipitation or irrigation, or the plant must draw upon stored soil water supplies. A six-year study at Fargo evaluated stand age effects on alfalfa productivity when annual precipitation differences were removed (Figure 3). Forage yields averaged 4.8 tons dry matter/acre during the first harvest year, 4.0 tons/acre in the second year, and 3.6 tons/acre in the third year, a decrease of 1.2 tons/acre between the first and third production years. The value of this loss of production will compensate for the cost of establishing a new stand.

Forage yields decreased with increasing stand age in all years tested in another experiment at Fargo (Table 2). The greatest decrease occurred in 1980, a very dry year. The three-year-old stand produced 54 percent less

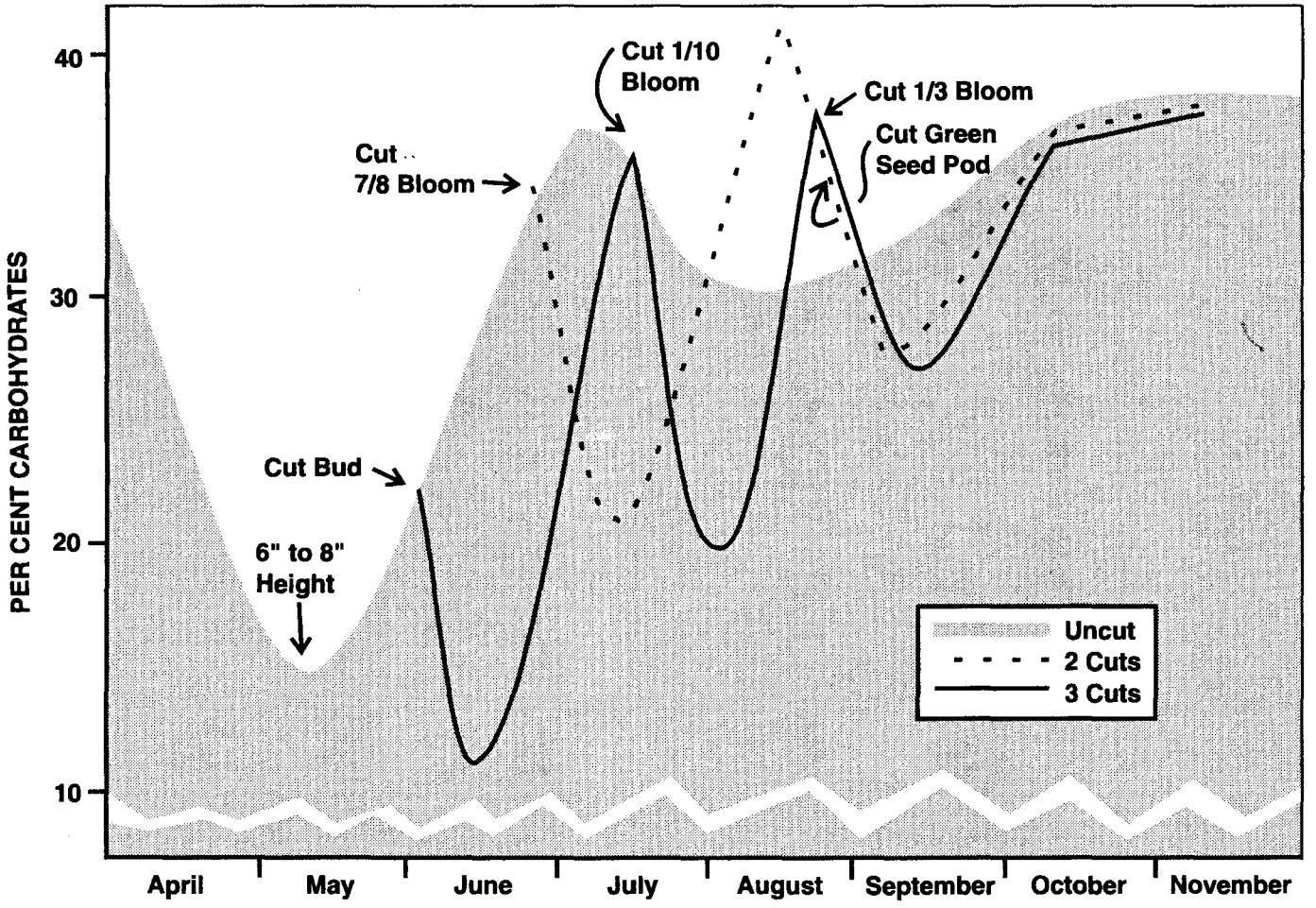


**Figure 2. Seasonal trends of total available carbohydrates in roots of Vernal alfalfa with two cuttings, three cuttings and with no cutting.** (Adapted from Forage Management in the North, by Dale Smith, 1962.)

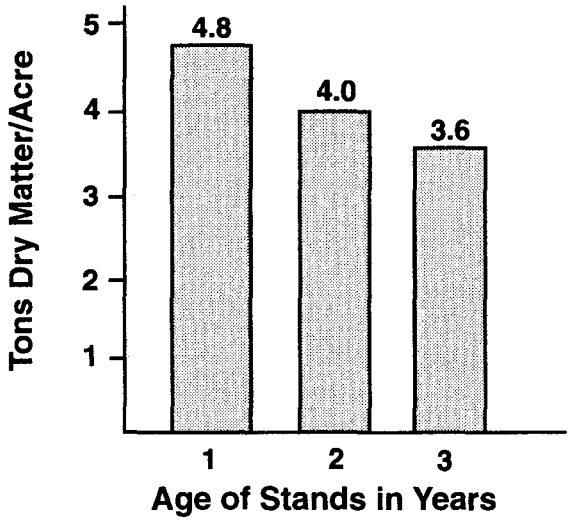


**Figure 3. Influence of age of stand on alfalfa forage yields, Fargo, ND.**

**Table 2. Stand age effects on alfalfa forage yield at Fargo.[1]**

| Stand age | Harvest year | | | | | |
|---|---|---|---|---|---|---|
| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
| Years | tons dry matter/acre | | | | | |
| 1 | 5.2a | 3.4a | 4.9a | 4.2a | 4.3a | 4.9a |
| 2 | 4.1b | 2.6b | 4.6a | 3.7a | 3.9ab | 4.6a |
| 3 | | 1.6c | 4.5a | 3.6ab | 3.4b | 4.6a |
| 4 | | | 3.9a | 2.9bc | 3.3bc | 3.6b |
| 5 | | | | 2.6c | 3.1bc | 3.7b |
| 6 | | | | | 2.5c | 3.2b |
| 7 | | | | | | 2.9b |

[1]Average of three varieties

forage than the one-year-old stand. But in average to above- average precipitation years like 1981 to 1984, stand age (three to four-year-old stands) had less effect on productivity. Older stands (six to seven-year old) were less productive, averaging nearly 2 tons/acre less. Much of the lower productivity of older dryland stands is because of depletion of deep subsoil moisture, but it may also be due to loss of plant density, accumulating winter injury/winterkill effects, and weed encroachment.

Irrigated alfalfa yields also decreased with stand age at Carrington (Table 3.) First-year productivity averaged 1.0 ton/acre greater than second-year and 2.1 tons/acre greater than third-year. Note that in 1990 a stand was winterkilled, but the zero yield was not included in the average, and the third-year productivity average is higher because of this deletion. The observed reduction in yield of irrigated alfalfa with stand age is believed to be associated with accumulating winter injury effects.

**Table 3. Stand age effects on irrigated alfalfa production.**

| Year of experiment | Harvest year First | Second | Third |
|---|---|---|---|
| | - - - - - - tons dry matter/acre - - - - - - - - | | |
| 1969-71 | 5.8 | 4.8 | 2.8 |
| 1973-75 | 5.0 | 3.7 | 3.7 |
| 1978-80 | 6.6 | 5.3 | 3.4 |
| 1979-81 | 7.2 | 5.2 | 3.7 |
| 1984-86 | 5.3 | 5.1 | 4.5 |
| 1987-90 | 5.0 | 5.4 | 0.0[1] |
| 1992-94 | 4.8 | 3.4 | -- |
| **Average** | **5.7** | **4.7** | **3.6** |

[1]Winterkilled, deleted from average

# Harvest Frequency

The number of cuttings obtained from an alfalfa stand depends on the available soil water for regrowth. In general, one to two cuts are usually obtained in central and western North Dakota and three cuts in the Red River Valley area and under irrigation. The growth stage at which first-harvest forage is removed has a major influence on forage quality. In addition, the later the first crop is removed under dryland conditions the less subsoil water available for regrowth. Only a small increase in forage yield is obtained by delaying harvest past the 10 to 20 percent bloom growth stage, but forage digestibility and forage intake by livestock decreases 0.3 to 0.5 percent per day.

Early alfalfa management studies at the Dickinson Research Extension Center (Table 4) show that an early two-cut system (June 20 and August 10 at 10 to 50 percent bloom) produced the greatest forage yields when compared with the late two-cut or full-bloom systems. Only limited fall regrowth was obtained from the early two-cut system. Forage quality of first-harvest forage is related to the growth stage when harvested, and even though the forage yields between early and late-bloom hays were similar, quality of the forage would dictate early harvest. The early two-cut harvest schedule produced the highest yield of quality forage and should be given consideration in the western one-half to two-thirds of North Dakota where only one to two cuts are usually obtained.

The Dickinson experiment (Table 4) was harvested by date, but a wiser management practice is to harvest alfalfa by growth stage. Highest three-year average

**Table 4. Three-year average forage yield by harvest frequency at Dickinson, ND.**

| Cutting schedule[1] | Cuts 1 & 2 | Fall | Seasonal |
|---|---|---|---|
| | - - - - - - - tons dry matter/acre - - - - - - | | |
| Early 2-cut | 3.5 | --- | 3.5 |
| Early 2-cut + 9/15 | 3.6 | 0.3 | 3.9 |
| Early 2-cut + 10/1 | 3.8 | 0.6 | 4.3 |
| Early 2-cut + 10/15 | 3.5 | 0.3 | 3.8 |
| Late 2-cut | 3.4 | --- | 3.4 |
| Late 2-cut + 10/1 | 3.4 | 0.0[2] | 3.4 |
| Full bloom | 2.6 | 0.0 | 2.6 |
| Full bloom + 10/1 | 2.4 | 0.9 | 3.3 |

[1]Early 2-cut = 6/20, 8/10; late 2-cut = 6/30, 8/30; full bloom = 7/11.

[2]Limited to no regrowth.

forage yields averaged over five varieties were obtained at Fargo with three harvests taken at appearance of first flower plus a fall harvest (Table 5). Three cuts on a calendar basis (June 15, July 20, and August 30 at about 10 percent bloom for Vernal) followed closely in yield. But note that the forage yield from the calendar schedule was the lowest in the third-harvest year. Unpublished data at North Dakota research centers (Table 6) also shows the value of early harvest in maintaining alfalfa productivity. Statewide average dryland yields increased with delaying harvest from late bud to the 10 percent bloom growth stage, but then decreased with further delayed harvest, primarily because of leaf loss caused by moisture stress.

**Table 5. Three year average alfalfa forage yields harvested by growth stage at Fargo.**

| Cutting schedule | | Harvest year | | | |
|---|---|---|---|---|---|
| | | First | Second | Third | Average |
| | Harvest | - - - - tons dry matter/acre - - - - - | | | |
| Calendar[1] | (3) | 6.0 | 4.6 | 4.1 | 4.9 |
| First flower (FF) | (3) | 5.5 | 4.4 | 4.2 | 4.7 |
| First seed pod (FS) | (3) | 4.7 | 4.1 | 4.3 | 4.4 |
| FF plus fall | (4) | 6.3 | 4.3 | 4.6 | 5.1 |
| FS plus fall | (4) | 5.3 | 4.5 | 4.7 | 4.8 |

[1]Harvested June 15, July 20, and August 30.

**Table 6. Three-year dryland forage yield of Vernal alfalfa by growth stage.**

| Location | Growth stage | | | |
|---|---|---|---|---|
| | Late bud | 10% bud | 50-75% bloom | First seed pod |
| | - - - - - - - tons dry matter/acre - - - - - - - - | | | |
| Dickinson | 1.6 | 2.1 | 2.2 | 2.0 |
| Fargo | 3.1 | 3.6 | 3.3 | 3.9 |
| Hettinger | 2.0 | 1.9 | 2.0 | 1.9 |
| Langdon | 3.1 | 3.8 | 3.3 | 2.6 |
| Minot | 3.1 | 3.2 | 3.3 | 2.8 |
| Williston | 2.3 | 2.8 | 2.2 | 2.1 |
| **Average** | **2.5** | **2.9** | **2.7** | **2.6** |

# Forage Quality

Forage quality of alfalfa decreases as maturity or growth stage increases. Crude protein and digestible dry matter decrease, while acid-detergent fiber (ADF) and neutral-detergent fiber (NDF) increase with advancing growth stage (Table 7). The increased fiber content and decreased digestibility sharply reduces the amount of forage intake, which lowers animal performance. A high-quality alfalfa hay should have a relative feed value (RFV) in excess of 150. Note that 10 percent bloom alfalfa hay had a RFV of 159 and basically a 20-30-40 (%) protein-ADF-NDF relationship. Most first-harvest 10 percent bloom hay, however, will not make RFV = 150 hay. Data in Table 6 used hand-harvested samples with no leaf loss. If a typical 15 percent leaf loss is assumed, the forage quality of the 10 percent bloom hay was reduced to that of the 80 percent bloom hay. This suggests that to obtain the 20-30-40 hay, harvest must occur before 10 percent bloom, at late bud or first flower.

Optimum management of alfalfa hay therefore is a compromise between quantity (yield) and quality. Under ideal conditions, late bud or first flower is the optimum growth stage to harvest alfalfa. But many factors may alter this optimum stage, including wet weather conditions during haying season, class of livestock fed, stored soil water, earliness or lateness of season, wet soils, and winter injury to stand.

**Table 7. Forage quality of alfalfa at three growth stages at Fargo in 1992.**

| | Growth stage | | |
|---|---|---|---|
| | Mid-bud | 10% bloom | 80% bloom |
| | - - - - - - - - % - - - - - - - - | | |
| Crude protein | 22.2 | 20.7 | 18.4 |
| Acid-detergent fiber (ADF) | 25.2 | 30.6 | 37.4 |
| Neutral-detergent fiber (NDF) | 33.3 | 39.4 | 48.2 |
| Digestible dry matter (DDM)[1] | 69.2 | 65.1 | 59.8 |
| Dry matter intake (DMI)[1] | 3.6 | 3.0 | 1.9 |
| Relative feed value (RFV)[1] | 199 | 159 | 125 |

[1] DDM % = 88.9 - (0.779 + ADF), DMI (% of body weight) = 120/NDF, RFV = (DDM + DMI)/1.29.

# Cutting Recommendations

**NEW PLANTINGS** of alfalfa utilizing clear or no-till seeding techniques should produce one or two harvests during the seeding year, especially in higher rainfall areas, on good moisture sites, or under irrigation. Alfalfa harvested during the establishment year should grow to the 10 to 25 percent bloom growth stage before harvesting the first cutting to enable the young plants to become well established, although earlier harvest has not been detrimental to stands in high-moisture areas. Alfalfa seeded with a companion crop usually does not grow tall enough after removing the companion crop for an economical forage harvest. If sufficient growth is obtained, it usually occurs in September and harvest should be delayed until air temperatures have dropped low enough to restrict regrowth, or until just prior to or immediately after the first killing frost.

**ESTABLISHED STANDS** should be harvested using a combination of growth stage and calendar date to determine the best harvest date. The first cutting must usually be taken before mid-June to allow time for three cuttings prior to August 20-25 in an average year. The first crop should be harvested by the 10 percent bloom stage (late bud to early bloom), especially in the Red River Valley area or under irrigation where three annual cuttings usually are obtained. Delayed harvest lowers the quality of the first harvest the most. Advantages of an early harvest are that a near maximum yield of quality forage is obtained, root reserves for regrowth have been adequately replenished, and soil water usually remains to initiate new growth. Forage quality of second and third-cut alfalfa is less affected by delayed harvest. Harvesting third cutting at 10 to 50 percent bloom will allow buildup of root reserves to aid in overwintering, and forage will be of high quality. However, remember that the alfalfa plant is ready to be harvested whenever regrowth has initiated at the bottom of the canopy, regardless of the maturity stage. Third-harvest irrigated alfalfa may initiate regrowth prior to initiating bloom due to the environmental conditions. In this case, harvest early enough so that most regrowth shoots are not removed.

Fall-stored soil water and May-June precipitation provide a good indication whether two cuttings are possible on old dryland stands. If adequate moisture is available, cut early to retain as much soil moisture as possible for regrowth. If soil moisture is limited or the alfalfa matures earlier than normal, harvest the crop at early bloom stages for best quality. In addition, the number of cuttings is limited by the percentage of grass in alfalfa-grass mixtures. Grass regrowth following harvest is very limited, so the percentage of alfalfa in alfalfa-grass mixtures usually determines whether a second cutting is economical.

If large acreages of alfalfa must be harvested, begin cutting early at the mid- to late-bud growth stage. This will yield a higher overall quality forage from all fields. Another alternative is to plant a portion of your acreage to Class 4 varieties. These varieties are usually one to several days earlier maturing than the more dormant types (Classes 2 and 3), permitting earlier harvesting.

# Bloom Stages

Harvest recommendations are based on the flowering growth stage of alfalfa - early bud; late bud; and 10, 20, and 30 percent bloom; etc. To determine bloom stage of alfalfa, randomly select 10 stems at several locations in the field. Count the number of stems and determine those which have one or more flowers open. If only one stem out of 10 has one or more flowers open, the crop is at 10 percent bloom. If all flowers are open on every stem, the crop is at full bloom.

# Stubble Height

The influence of stubble height and cutting frequency on forage production and quality was studied at Fargo (Table 8). Stubble heights of 1 inch to simulate mower bar harvest and 3 to 5 inches to simulate swather harvest were used. Forage production was slightly higher under the two-cut system; however, the quality of hay

**Table 8. Dry matter, protein, and digestible-forage yields of alfalfa by stubble height and harvest frequency at Fargo.[1]**

| Stubble height | Dry matter | Protein | Digestible forage |
|---|---|---|---|
| | tons/acre | lb/acre | tons/acre |
| | **2 cuts[1]** | | |
| 1 inch | 5.0 | 1750 | 3.1 |
| 3 inch | 4.5 | 1600 | 2.9 |
| 5 inch | 4.1 | 1530 | 2.7 |
| | **3 cuts[1]** | | |
| 1 inch | 4.9 | 2000 | 3.2 |
| 3 inch | 4.6 | 1940 | 3.2 |
| 5 inch | 3.7 | 1650 | 2.5 |

[1]Approximate harvest dates: 2-cut = July 1, August 31; 3-cut = June 15, July 25, August 31.

as indicated by protein and digestible forage per acre was superior from the three-cut system. Increasing the stubble height increased the percent protein and digestibility of the forage but reduced forage production about 0.5 ton/acre for each 2 inches of stubble left standing in the field. Protein and digestible forage yields per acre of the 3-inch stubble height of the three-cut system, however, were similar to the 1-inch stubble height. This indicates that the swather can be used efficiently to harvest alfalfa if operated to obtain the lowest stubble height possible. However, presence of pocket gopher mounds frequently causes excessive stubble heights and resulting yield losses.

## Harvest Losses

Harvesting losses in field curing of alfalfa can be great, as shown by research in South Dakota. Researchers found that the amount of dry forage recovered in the bale compared with the amount actually present in the field was greatest when forage moisture levels were greater than 40 percent. Dry forage recovered as baled hay averaged 79 percent, but 95 percent was recovered when harvested as haylage (Figure 4). In one instance, two rains amounting to 0.82 and 0.12 inches made it necessary to rake the swaths twice before baling. Forage recovery was 82 percent when swaths were not turned, but only 54 percent when swaths were turned by raking. Principal loss was due to leaf shattering by harvesting machinery. Leaf losses during harvesting increased rapidly at moisture levels less than 30 percent and were especially high at moisture levels less than 20 percent.

Reduce leaf loss when field-curing alfalfa by using hay "conditioners," crushers, or crimpers. These machines break the alfalfa stem, allowing a faster, more uniform dry-down of stems relative to leaves. Proper use of drying agents like potassium or sodium carbonate can also reduce drying time, but drying agents do not work well in poor drying conditions. The reduced drying time also reduces the chance of rain before storage. High-moisture hay preservatives like propionic acid applied at a rate of 0.5 to 1.0 percent of wet weight to 25 to 30 percent moisture hay can also reduce harvesting losses and help prevent rain damage.

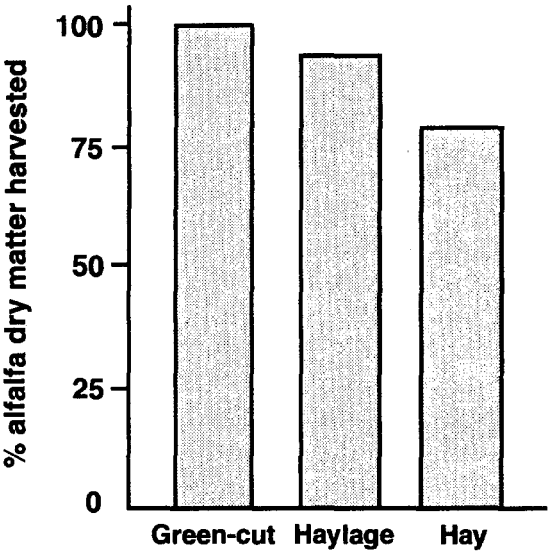


**Figure 4. Percentages of dry matter harvested in field curing of alfalfa.** (From SD Farm & Home Research, Vol. 22, No. 3, Summer 1971)

## Grass-Alfalfa Mixtures

Forage yields are generally higher with pure stands of alfalfa in North Dakota where adequate moisture permits a second harvest. Grasses are recommended in mixtures with alfalfa for pasture. Pasture plantings containing 70 percent grass and 30 percent alfalfa have less bloat hazard than pure alfalfa, especially with proper grazing management. Grasses produce the major portion of their growth early in the season, usually permitting only one cutting. Therefore, pure stands of alfalfa or, if mixtures are desired, stands with more than 50 percent alfalfa should be used for highest annual hay production.

## Fall Harvest Management

Late summer to early fall is important in the life cycle of an alfalfa plant. The plant must store food reserves to develop cold resistance, supply overwintering respiration, and to initiate growth during the spring. If alfalfa goes into the winter with a low level of food reserves, it is more subject to winter injury or winterkill. However, low root reserves does not dictate that winter injury or kill will occur. Winter injury/kill is determined by environmental conditions (usually a warm spell during late February to early March which initiates loss of dormancy and subsequent killing temperatures). Fall harvest may be detrimental under these conditions, but such environ-

mental conditions are fairly unusual, maybe once every four to six years.

Many experiments have evaluated effects of fall harvest on forage yield and stand survival within North Dakota. Generally, fall harvesting in late September or very early October has increased seasonal productivity (Tables 4 and 5). Fall harvest date effects were evaluated in a recent experiment at Fargo by harvesting plots at weekly intervals from August 27 to October 28 following a second harvest on July 20 (Table 9). Third-harvest and seasonal forage yields in 1992 were greatest with September harvest of this new stand. Harvesting during October resulted in lower forage yields due to leaf loss following a killing frost. First-harvest forage yields in 1993, however, were greatest from the uncut and October 1992 harvests. About 0.4 tons/acre of the uncut yield was low-quality alfalfa stems from the previous fall, but no residue was left in late October-harvested plots. These data, repeated in 1993-94, suggest that a late September or early October fall harvest should be taken when adequate growth justifies the additional harvest. However, several management experiments suggest that alfalfa should not be harvested during late August or early September. Note that the calendar schedule (Table 5) was the lowest yielding by the third-harvest year. Harvest before or about August 20 or wait for mid to late September.

Taking a fall harvest does slightly increase the risk of winter injury/kill. However, the additional productivity that the fall harvest supplies in most years more than offsets this increased risk.

If you consider taking a fall harvest, be sure you meet the following criteria:

1. A winter-hardy variety was used. Varieties marginal in winter hardiness should not be harvested during the fall.
2. Soil fertility, especially potassium, is adequate.
3. Only short-term (three to four productive years) stands are used. If you plan to maintain the stand for five plus years, a fall harvest probably should not be taken.
4. Be sure the alfalfa has reached 15 to 20 percent bloom, has initiated regrowth structures, **OR** a killing frost has occurred.
5. Uncut barriers 1 to 2 feet wide every 30 to 40 feet across the field are left perpendicular to the prevailing winter wind to improve snow cover. If the fall harvest is by grazing animals, be sure to leave a 4 to 6-inch stubble for snow catch. If the fall harvest is the fourth cut, be sure to wait with the harvest until a killing frost has occurred.

**Table 9. Forage yield in 1993 following weekly harvest in 1992.**

| 1992 third harvest date | 1992 forage yield Cut 3 | 1992 forage yield Total | 1993 forage yield Cut 1 | 1993 forage yield Total[1] |
|---|---|---|---|---|
| | tons dry matter/acre | | | |
| August 27 | 1.4 | 6.0 | 1.6 | 3.6 |
| September 2 or 9 | 1.7 | 6.3 | 1.6 | 3.4 |
| September 16, 23, or 30 | 1.6 | 6.3 | 1.7 | 3.6 |
| October 7 or 14 | 1.4 | 6.1 | 1.9 | 3.7 |
| October 21 or 28 | 1.0 | 5.7 | 2.0 | 3.9 |
| Uncut | 0.0 | 4.7 | 2.1 | 4.0 |

[1] Only two harvested, third was lost to drown out.

# Winter Injury

Winter injury or winterkill will periodically occur even with the best management practices. In general, old stands are more likely to winterkill or have winter injury than new seedings or relatively young stands. Several environmental factors may contribute to the degree of winter injury or winterkill. These factors include alternating freezing and thawing, lack of snow cover, wet soil conditions, disease infection, low soil fertility, unfavorable fall weather conditions for plant hardening, and cold temperatures. Grower management practices such as varietal selection, age of stand, and fall-harvest management practices are major considerations for maintaining productive stands.

Alfalfa winterkill is the result of complete killing of plant cells of the crown and root tissues. Stands severely thinned by winterkill will be low yielding and heavily infested with weeds. If winterkill is severe, establish a new stand, but rotating to a new field is best, especially if stands are two or more years old. Alfalfa is known to contain an autotoxic compound which may inhibit immediate re-establishment in the same field.

Winter injury is the result of only a partial destruction or killing of the crown or root tissues. Winter-injured stands are usually slow to begin growth in the spring. The plants may look normal but are weak, stunted in growth, yellowish in color, and they may have a limited number of stems developed per crown. If two to three plants/foot$^2$ remain in most areas of winter-injured stands, satisfactory yields probably will be obtained. If small areas have as little as one plant/foot$^2$, forage yields probably will be adequate since stands established at one plant/foot$^2$ had 78 to 84 percent of yield of full stands. If grass comprises the major portion of the plant population, forage yield should be satisfactory

even with a major loss of alfalfa. If only limited areas show winterkill, try no-till seeding of the damaged area and a herbicide to prevent weed competition. Then, do not harvest this area during the first cut only.

Wintered-injured stands require time to heal injured tissues if they are to survive and regain their vigor. Delay harvesting the first cutting until the 50 percent bloom growth stage. The area injured will be just beginning bloom. Early harvest of winter-injured stands may kill the injured plants or keep them in a weakened condition.

## Spring Frosts

The growth of each alfalfa stem takes place at the tip. A late spring frost may destroy the growing point of alfalfa, causing a stunting of the plant. A good "thumb rule" to follow is that if one-third or more of the top growth has been wilted by frost and drying up, immediate mowing will permit earlier development of a new crop. If the damage is less, the plant should recover adequately to allow harvest at the normal time. Harvest of frosted stands that were clipped should be delayed to about the mid-bloom growth stage for the second harvest to allow recovery of stored food reserves.

## Drought Stress

Drought may restrict or stop the growth of alfalfa at any time during the growing season. Alfalfa under moisture stress may lose its leaves, resulting in low-quality forage. Warm temperatures often accompany drought periods, reducing the time required for the plant to reach maturity. If the maturity of the alfalfa plant has advanced to the flowering growth stage before the drought is broken, the plant will continue to flower and set seed before new growth is initiated from the crown. Regrowth will be slow. The maturing alfalfa will continue to use the limited soil water supplies which could be used for producing a new crop of forage. In general, severely drought-stressed alfalfa should be grazed, or cut for hay if harvestable forage is present, to encourage a new crop once the drought is broken.

Drought-stress effects are reduced by keeping stands young. Young (1- to 2-year old) stands have subsoil moisture available to help maintain productivity (Table 2).

## Soil Fertility

The response of alfalfa stands to phosphorus and potassium fertilization has been variable throughout North Dakota. Alfalfa on low-testing soils often will respond to added phosphorus or potassium while alfalfa on soils testing medium to high in these nutrients generally does not respond. Growers should obtain a soil test and fertilize a portion of their fields to determine the potential for yield increases.

Alfalfa is a heavy user of potassium. Alfalfa hay contains from 2 to 3 percent potassium in the forage. Therefore, alfalfa yielding 3 tons/acre will remove from 120 to 180 pounds of potassium per acre. Most North Dakota soils test high in available potassium, so potassium fertilization generally is not needed, with the exception of some sandy irrigated soils. In an irrigated, sandy loam soil in McHenry County, for example, best yields were obtained from alfalfa hay when both phosphorus and potassium fertilizer were applied.

Preliminary studies by the NDSU soils department and extension service field demonstrations indicate that alfalfa stands will respond to phosphorus fertilization when the soil test is about 5 pounds $P_2O_5$/acre or less. A dryland alfalfa fertilization study in McHenry County showed a marked response to phosphorus on a soil testing 4 lb/acre. They obtained 4.0 to 4.5 tons/acre when 50 pounds of $P_2O_5$ were applied compared with about 2.0 tons/acre without phosphorus fertilization.

Extension service field demonstrations show similar results on grass-alfalfa mixtures. Five-year average forage yields from a fertilizer demonstration in Morton County on a soil testing 2 pounds $P_2O_5$/acre was 1.1 tons/acre without fertilization and 2.3 tons/acre with 40 pounds/acre $P_2O_5$. Phosphorus fertilization also appeared to increase the percentage of alfalfa in the stand. An application of 30 pounds N and 40 pounds $P_2O_5$/acre increased yields to 2.7 tons/acre and maintained the stand of alfalfa.

Alfalfa and grass-alfalfa mixtures containing 30 percent or more alfalfa are fertilized to maintain alfalfa in the stand since alfalfa is a high-yielding, higher-quality forage. Phosphorus increases the ability of the alfalfa plant to maintain itself in the mixture. Nitrogen increases grass yields, but high rates usually increase grass growth and decrease alfalfa in the mixture. In the Morton County demonstration, 60 pounds N/acre applied annually eliminated alfalfa from the stand when harvested at late-bloom growth stages. Alfalfa properly inoculated at planting time will usually not respond to

nitrogen fertilization except in very cold soils in early spring.

Phosphorus and potassium recommendations for dryland and irrigated alfalfa based on your yield goal are presented in Table 10 . Note that modest phosphorus and potassium fertilization is recommended on medium testing soils even though a large increase in forage yield is not expected. However, the yield increase will just pay for the fertilizer, and fertilization will help maintain long-term soil fertility. Fertilizer for alfalfa is generally broadcast, although yield increases from deep-plowed phosphorus has been reported in North Dakota.

One of the obstacles to good alfalfa production in the United States is maintaining soil pH of 7.0 or higher. In North Dakota, most soils have pH higher than 7.0, so pH generally is not a concern.

# Irrigation Water Management

The amount of irrigation water required by the alfalfa crop will vary according to environmental conditions, growth stage, stored soil water, and growing-season precipitation. Water use by the alfalfa plant increases from the time growth begins in the spring until the plant reaches about a 12-inch height or full ground cover. From this stage on, water use averages about 0.25 inches/day until harvest. Studies in North Dakota show that near maximum forage yields are obtained when soil water levels are maintained above 50 to 60 percent of field capacity. Knowledge of the available water-holding capacity of soils and the amount of precipitation between irrigations will serve as a guide to irrigation water application. Several irrigation scheduling methods are available to aid irrigators.

# Production Economics

The decision to raise alfalfa has historically been based on the need for forage to feed livestock on the farm rather than on comparable profitability with other crops. The most profitable crop plan in the short run is to devote all acreage to the single most profitable crop, but this increases risk and is generally not sustainable. The crop mix on a farm should consist of those crops that generate the greatest profit long term. This means the sustainability or the risk associated with production and marketing of each crop in that mix must be considered.

Whether used for feed on the farm or sold as a cash crop, alfalfa must compete for alternative uses for land. In some situations, purchasing the needed alfalfa and producing another crop on the farm may be more profitable than producing the alfalfa. This decision should be based on crop budgets which include the three determinants of profitability: production cost, yield, and price.

An alfalfa budget differs from budgets for annual crops in that the seeding and establishment costs need to be prorated over the life of the stand. For the seeding year, these costs seem high relative to many other crops. However, when spread over the full life of the stand these costs are comparable to small grain.

**Table 10. Nutrient recommendations for alfalfa.**

| | | Soil test phosphorus, ppm | | | | | Soil test potassium, ppm | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | VL | L | M | H | VH | VL | L | M | H | VH |
| **Yield Goal** | **Bray-I Olsen** | 0-5 0-3 | 6-10 | 11-15 8-11 | 16-20 12-15 | 21+ 16+ | 0-40 | 41-80 | 81-120 | 121-160 | 161+ |
| **ton/a** | | lb $P_2O_5$/acre | | | | | lb $K_2O$/acre | | | | |
| 2 | | 35 | 25 | 15 | 10 | 0 | 105 | 75 | 45 | 10 | 0 |
| 4 | | 65 | 50 | 30 | 10 | 0 | 195 | 140 | 80 | 25 | 0 |
| 5 | | 85 | 60 | 40 | 15 | 0 | 245 | 170 | 100 | 30 | 0 |
| 6 | | 100 | 70 | 45 | 15 | 0 | 295 | 205 | 120 | 35 | 0 |

Bray-I P recommendation = (18.57-0.93 STP)YG
Olsen P recommendation = (18.57-1.16 STP)YG
Potassium recommendation = (55.71-0.38 STK)YG

The abbreviations used in the equations are as follows:
YG = yield goal
STP = soil test phosphorus
STP = soil test potassium

Table 11.

| Alfalfa - 4 Year Life | Round Bales | | Square Bales | | Your Figures |
|---|---|---|---|---|---|
| | Dryland | Irrigated | Dryland | Irrigated | |
| **Market Yield (tons/acre)** | **2.3** | **4.875** | **2.3** | **4.875** | |
| **Market Price ($/ton)** | $ 55.00 | $ 55.00 | $ 70.00 | $ 70.00 | |
| **Market Income (Per Acre)** | $126.50 | $268.13 | $161.00 | $341.25 | |
| **Direct Costs** | | | | | |
| Seed | $ 6.25 | $ 6.25 | $ 6.25 | $ 6.25 | |
| Herbicides | 3.32 | 4.94 | 3.32 | 4.92 | |
| Fertilizer | 3.27 | 8.08 | 3.27 | 8.08 | |
| Fuel & Lubrication | 9.47 | 11.93 | 12.54 | 15.00 | |
| Repairs | 16.54 | 17.55 | 16.79 | 17.79 | |
| Irrigation Expense | | 39.19 | | 39.19 | |
| Twine, Misc. | 3.41 | 5.98 | 3.41 | 5.98 | |
| Operating Interest | 1.85 | 4.11 | 1.99 | 4.25 | |
| **Sum of Listed Direct Costs** | **$ 44.11** | **$ 98.02** | **$ 47.56** | **$101.46** | |
| **Indirect (Fixed) Costs** | | | | | |
| Misc. Overhead | $ 6.39 | $ 7.80 | $ 6.90 | $ 8.31 | |
| Machinery Depreciation | 24.21 | 27.98 | 26.01 | 29.77 | |
| Machinery Investment | 12.74 | 15.47 | 14.04 | 16.76 | |
| Irrigation Depreciation | | 25.34 | | 25.34 | |
| Irrigation Investment | | 17.42 | | 17.42 | |
| Land Taxes | 4.97 | 4.97 | 4.97 | 4.97 | |
| Land Investment | 34.66 | 34.66 | 34.66 | 34.66 | |
| **Sum of Listed Indirect Costs** | **$ 82.97** | **$133.64** | **$ 86.57** | **$137.24** | |
| **Sum of All Listed Costs** | **$127.07** | **$231.66** | **$134.13** | **$238.69** | |
| **Return to Labor & Management** | **($ 0.57)** | **$ 36.47** | **$ 26.87** | **$102.56** | |
| **Listed Costs Per Ton** | | | | | |
| Direct Costs | $ 19.18 | $ 20.11 | $ 20.68 | $ 20.81 | |
| Indirect Costs | 36.07 | 27.41 | 37.64 | 28.15 | |
| Total Costs | 55.25 | 47.52 | 58.32 | 48.96 | |

Alfalfa can be harvested as small square bales, large square bales, round bales, chopped as haylage, or stacked as loose hay. The cost of producing hay varies considerably using different harvest methods. In addition to the difference in costs, market price also differs. Prices will vary by regions of the country, but in the Midwest, small square bales usually bring a premium price relative to other harvesting methods. The enterprise budgets in Table 11 outline the cost and returns for alfalfa for southeastern North Dakota harvested as small square bales and as large round bales.

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These budgets are based on costs incurred to produce the crop in the field. They do not include any costs associated with storage and marketing. Likewise, the price also reflects the value of the crop in the field at harvest. Storage protection and/or losses can add up quickly. In addition, transportation costs to move alfalfa hay any distance will add considerably to the cost of the hay. Therefore, relating the market value of the hay with the location and time of sale is important. A price of $70 per ton picked up in the field at harvest in eastern North Dakota may be nearly identical to a price of $100 per ton delivered to south central Minnesota six months later.

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