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Mountain Meadow Improvement in Wyoming

by Rulon D. Lewis

Agricultural Experiment Station
University of Wyoming

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Bulletin 350

In Cooperation with the
U.S. Department of Agriculture
SUMMARY AND RECOMMENDATIONS

Research results and rancher experience show that there are four major steps involved in the improvement of hay and pasture production in the mountain meadows of Wyoming.

I. Water Control Essential: Top production is not possible under the wild-flooding irrigation method that is used on many mountain-meadow ranches. Field results show that intermittent rather than continuous wild-flood irrigation is necessary to establish and maintain good stands of high-yielding forage species. The highest profits from nitrogen fertilizer and the most efficient water use on either deep or shallow soils has been obtained with intermittent irrigation. A general recommendation for maximum yield of high quality hay is to irrigate by applying 1 to 3 inches of water over a period of 1 to 8 hours, depending on soil depth and texture at 2-week intervals at the beginning of the season and at 1-week intervals during the peak of the growing season. The peak growing season usually occurs from mid-June to the end of July, depending on the particular location.

In some areas, adequate water control for intermittent irrigation can be accomplished by individual ranchers, but in other cases water diversion, drainage, or temporary storage of water supply will be required; this may involve coordinated action by several ranchers.

II. Establishment of Higher-Yielding Forage Species: Ranchers can establish higher-producing forage species in several ways, depending upon soil depth.

In areas with relatively deep surface soils, the meadows can be plowed, leveled, and seeded. In most cases, it is desirable to grow an annual crop such as oats, or oats and peas, for one to three years, to allow the sod to decompose and to permit final leveling and seedbed preparation. In shallow soils with just a few inches of topsoil overlying gravel, plowing and leveling are not desirable, and the rancher must resort to renovation or broadcast methods to incorporate higher-producing forage species.

III. Nitrogen Fertilization Shows Promise: Nitrogen fertilization has given large increases in yield and quality of hay when used with higher-yielding forage species and adequate water control. When considering only hay tonnage, the 80-pound nitrogen applications gave the most economical returns. However, when protein content was also considered, the 160-pound rate of nitrogen paid best.

IV. Time of Harvest Important: The highest yields of high-protein hay are obtained when higher-producing forage-grass species are cut not later than when the seed is at soft-dough stage. As the forage species mature, crude protein declines, and the hay becomes coarse and low in palatability. When grass forage is cut before or during the soft-dough stage and fertilized with high rates of nitrogen, most species will produce aftermath growth high in protein if proper irrigation and soil-management practices are used. This aftermath can be cut for hay or pastured later in the summer or in the fall.
Mountain Meadow Improvement

In Wyoming

By Rulon D. Lewis

The total acreage of mountain meadows in the 11 Western states comprises about 3,800,000 acres. In Wyoming the total acreage of irrigated native-meadow hay harvested in 1953 was 343,500 acres. This was 44 percent of all irrigated hay harvested in the state. The average yield from these meadows has declined from about 1 ton per acre in 1910 to 4/5 ton per acre in 1953 (Fig. 1). This decline amounted to an annual loss of 68,700 tons of hay by 1953.

Stockmen in Wyoming have depended upon mountain meadowlands for 4 to 6 months' winter feed to support their livestock enterprises for the past 75 years or more. The meadows are used also in the spring and fall for pasture after the ranges have dried up. Forage produced from these meadowlands in the form of hay and pasture determines beef production.

FIG. 1—Average hay yield of approximately 4/5 ton per acre. Shallow gravelly loam soil. Little Laramie River basin, 1955.

1This work is the result of cooperative investigations between the Wyoming Agricultural Experiment Station and the Soil and Water Conservation Research Branch, Agricultural Research Service, U.S.D.A. The author expresses appreciation to Robert L. Lang, associate agronomist, Wyoming Agricultural Experiment Station; Byron R. Tomlinson, Irrigation Engineer, Soil Conservation Service, U.S.D.A.; Department of Research Chemistry, Wyoming Agricultural Experiment Station; and commercial fertilizer people who contributed the fertilizer material used in the research program. Credit is due the Soil Conservation Service for the cover-page photograph.

PRESENT MANAGEMENT PRACTICES

Early settlers started irrigation and sagebrush- and willow-removal practices in the meadow areas in about 1870. Little of the land was plowed or leveled. Instead, dikes were erected, generally of earth or barnyard manure, to force the water to flood the high ground, from which it later drained into the flatter areas. These dikes dam up water over the lower spots, from which it escapes only by evaporation or percolation, with resultant leaching of the low spots and the development of water-loving vegetation. Dry hummocks occurred frequently throughout the fields. If the soil or irrigation water contained salts, they often accumulated on the surface of these hummocks.

Small irrigation ditches were sometimes built to follow the contour of the higher land on lands too rough and steep to be flooded by use of dikes.

Over the years the general custom has been to turn water into the meadows soon after the snow cover has disappeared in late spring, and allow it to run continuously until late July (Fig. 2). At that time the water is turned off to allow the soil to dry before harvesting the hay crop.

Cattle Management

Many ranchers and stockmen are aware of the declining quality and yield of forage in their meadow areas. The amount of winter hay and of spring and fall pasture produced determines largely the number of cattle a ranch may carry. Through study and adaptation, the livestock producers have developed a sys-

FIG. 2—Typical wild-flood irrigation. Pinedale, Wyoming.
tem of management suited to present range pasture and meadow-forage production (Fig. 3).

The system of wintering the livestock on ranches is general throughout the state. When the stock return from the mountains in the fall, usually in October, they graze the meadows until snow falls. The meadows are generally depleted of forage by the time snow covers them in November. Forage, chiefly native hay, is hand-fed back on the meadows until the pasture opens in the spring. The cattle graze the meadows until the summer ranges are available and ready.

Haying

The forage produced on these ranches is for the most part sedges and rushes, which are the result of the irrigation practices followed. Timothy, reedtop, and alsike clover are generally found where less irrigation water is used.

Meadows of these native types produce but one crop of hay annually; this yields an average of 4/5 tons to the acre. Haying operations start about the first of August and continue for a month or 6 weeks. The forage is usually allowed to reach full maturity before harvest. The hay is stored in stacks averaging approximately 20 tons each. These are fenced until stock-feeding time.

Winter Feeding

In the winter, ranchers feed their cattle daily by hauling hay from the stacks and scattering it on the ground or snow. The winter feeding period begins about November 1 and ends between April 15 and May 15. The amount of hay fed per animal unit varies from 3/4 to 2 tons, depending on the length of the winter season, with an average of about 1 1/3 tons.
Spring Grazing

There is often a shortage of spring grazing, since the cattle are not permitted on the forest ranges until about the first of June. The foothills and adjacent open ranges do not provide food enough to last until the forest range opens. In many cases this necessitates grazing the meadows late in the spring.

AREA RESOURCES

Soils

The high-altitude meadows are generally located in stream-cut valleys on stream-deposited debris of variable depth and texture. The soils found in these valleys are classed in two general groups having contrasting physical features, recognized as important to land use and management.

One group of soils occurs largely on coarse material containing large quantities of gravel and cobble. They are coarse-textured and lack depth to the underlying unconsolidated gravelly and cobbly material of low water-holding capacity. A typical soil has a thin surface 3 to 4 inches thick and is underlain by earthy, coarse sand and gravel to a depth of 10 to 20 inches, whereupon clean, loose gravel is encountered. Such soils are inherently low in fertility; the supply of water they are capable of holding can readily be exhausted by a vigorous crop. Keeping the soil-moisture content at optimum for plant growth requires frequent irrigation. These soils do not respond well to good management.

In contrast, soils of the second group develop on a mixed material which originates as wastes from limestones, sandstones, and shales. They are fine-textured and with good depth to deposits of gravel. Ordinarily they have a high water-holding capacity, making less frequent irrigation necessary to maintain favorable soil-moisture conditions. The inherent fertility is fair to high, except for available nitrogen content. In the majority of localities they have favorable tilth characteristics. Such soils respond favorably to management and have a high-production potential.

Meadow haylands often occur where complex patterns of the two described types of land prevail. Obviously, irrigation and fertility management becomes a difficult problem to the land manager. His solution has led to the adoption of continuous wild-flood irrigation, which in turn has brought about an environment unfavorable to growth of the higher-producing species of grasses and clovers. No matter what type of soil was available, the tendency for years has been to apply the same management practices. As a result, ranchers have not received all the benefits that the better soils were capable of producing.

A third group of soils, known as the "alkali types," are also recognized as an important group in the mountain-meadow hayland area. Some of these soils were identical, in many features, to those of group 2 at one time, but, because of location and subsequent use of ground water, they have become "alkalied". Commonly, they occur along the outer borders of valleys where the valley fill makes contact with the rougher lands underlain by saline-alkaline shales. Elsewhere, these saline-alkali soils occur in narrow swales and on fans from wastes of barren
shale deposits. Such soils present rather complex problems in management and reclamation to prepare them for production of the better species of grasses and clovers. Since their improvement requires special treatment, further discussion regarding their management is excluded from this report.

Climate
In the western part of Wyoming, most of the meadows occur at elevations above 7000 ft. The water supply for irrigation is ample during the growing season, and the area is generally covered with snow during the winter and early spring months. The growing season is short, varying from 50 to 90 days. In many of the more elevated localities in this section, freezing temperatures may be expected every month of the year. Nights are cool, and although the sunlight is intense, the mean daily temperatures are relatively low. The average annual rainfall varies from 10 to 18 inches. The heaviest amounts of precipitation are mostly in the form of snow.

In the eastern part of the state, the meadow areas are at varying elevations of from 5000 to 8000 ft. In general, the water supply for irrigation is ample during the early part of the growing season but becomes inadequate after mid-July. The area is often free of snow cover for long periods during the winter months, and the soil becomes cold and dry, which causes many high-producing species of grasses and legumes to “drought-out” and winterkill. The growing season varies from 60 to 110 days. The nights are cool, but the mean daily temperatures are slightly higher than those in the western part of the state. The average annual rainfall varies from 10 to 17 inches.
Differences in elevation within each area are of great importance, as they affect the length of the growing season. At elevations of 6000 ft. the average annual length of the growing season is 90 days. At 8500 ft. it is 60 days.

**Meadow Vegetation**

Most of the meadow vegetation found today includes water-loving plants such as sedges (Carex species), wiregrass (Juncus species), watergrass, and weeds, with swamp species in the wetter parts of the meadow. Some meadows include scattered stands of timothy, redtop, alsike clover, and other higher-producing grass and legume species that ranchers have seeded in past years. These plants have survived around the outer edges of the valleys and within the valleys on small land areas where the elevation is sufficient to permit the water table to be several inches below the ground surface, allowing the soil to be aerated (Fig. 4). However, the higher-producing species have not survived on the low-lying, over-irrigated meadows, where the water table is close to or above the soil surface; such a situation inhibits soil aeration.

The continuous wild-flood irrigation method practiced in most of the mountain-meadow areas results in high water tables during the growing season and causes a decrease in the quantity and quality of hay produced. The forage harvested today from these wet meadow lands consists almost entirely of rushes and sedges, which produce low yields of hay compared with higher-producing forage species.

The continuous wild-flood method of irrigation also results in a sod-mat of undecomposed organic matter which is difficult to plow or break up (Fig. 5). Ranchers find that two or more years are necessary for decomposition of this sod after it is broken up, before the land can be properly prepared and leveled for best water management and reseeding.
The potential production of mountain meadows in Wyoming and throughout the mountain sections of the West is considerably greater than present yields indicate. For example, this production can be increased from the present-day average of 4/5 ton of hay per acre to between 3 and 5 tons of hay annually by applying the knowledge gained through research. The potential production of an area depends on the climate and skill used in managing the soil and on available irrigation water.

Research conducted in Wyoming and Colorado since 1949 has developed certain management practices that will help ranchers attain the maximum potential production. Application of these management practices will result in (1) reducing the area of meadowland needed to produce forage for winter feeding and (2) increasing the meadowland available for pasture. This indirectly will provide for better range conservation.

In 1949 the Agricultural Research Service of the U. S. Department of Agriculture and the Wyoming Agricultural Experiment Station began cooperative research in the high-altitude mountain-meadow areas of Wyoming. The purpose was to learn how to improve the production of the meadowlands.

The problems which must be solved to obtain maximum potential production in meadow areas are complex and numerous. We can, however, group these meadow-improvement problems into five broad categories: (1) water control, (2) establishment of higher-producing forage species, (3) fertilization, (4) harvesting practices, and (5) grazing management on meadows. Some of the improved practices which can be applied to individual fields may be adopted by individual ranchers. Still, it is recognized that some of these improved practices, such as water control, are far-reaching and may require coordinated action by several ranchers. Research has been conducted on some phases of these problems and is being continued. This bulletin is a brief report of the progress to date.

**Water Control Essential**

Continuous wild-flooding has caused a decline in forage yields in many of the mountain meadowlands. The water supply for irrigation and its management on different soil types largely determine how meadows can be improved. The main methods of irrigation used in the mountain-meadow areas are (1) continuous surface application, (2) occasionally intermittent surface applications, and (3) sub-irrigation.

Basic research studies were started in 1949 in a meadow area located on a deep sandy loam soil in the Green River Valley at Pinedale to compare the water requirements and the management practices for reseeded higher-yielding forage species and native-meadow species. The results show that native-meadow species required approximately 12 inches of water to produce a ton of hay; alsike clover/brome grass mixture about 6 inches of water; and a complex grass/legume mixture, which
included 5 grasses and 4 legumes, 7 in. of water per ton of hay (Fig. 6).

In May 1951 another study was started at Pinedale to compare the yields of hay produced by intermittent and wild-flood irrigation from a second-year seeding of alsike/brome mixture and native rush/sedge meadow. Results of the study with alsike/brome mixture, without applied nitrogen, show that the yield of hay produced from intermittent irrigation was 1.7 tons of hay per acre annually. With continuous wild-flood irrigation the yield of hay for the first 3 years was 1.0 ton annually and for the last two years, 0.5 ton annually. This decrease in yield to an average of a half ton of hay per acre for the last 2 years was due to decrease in the stand of the seeded alsike clover and bromegrass.

By the end of 3 years the alsike clover and bromegrass had practically all disappeared because of too much water, and lower-yielding native grasses, rushes, and sedges were becoming estab-
lished. At the end of 5 years the alsike clover/brome grass mixture with intermittent irrigation had produced an average of 1.7 tons of hay annually with a yield of 1.6 tons in 1955. With continuous wild-flood irrigation the average yield was 0.8 ton of hay per acre annually for the 5-year period, with a yield of 0.5 ton in 1955.

The results comparing intermittent irrigation with wild-flood irrigation on native-rush/sedge-type meadow without applied nitrogen show that the average yield of hay was 0.9 ton per acre annually for intermittent irrigation and 1.4 tons annually for continuous wild-flood irrigation. The difference of 0.5 ton in favor of continuous wild-flood irrigation was due to the high water requirements of the native grasses, rushes, and sedges which were prevalent in the native-rush/sedge-type meadow. With continuous wild-flood irrigation, moisture conditions were more favorable for the kind of vegetation present to result in the higher yield.

Results of irrigation studies conducted with higher-yielding forage species show that the highest yields of hay and the most satisfactory stands were maintained over a period of 5 years under controlled intermittent irrigation, with 2 to 3 inches of water applied over a period of 7 hours every 10 to 14 days at the beginning of the growing season, and every 5 to 7 days during the peak growing period. On native-rush/sedge-type meadow, the highest yields of hay were produced over the same period of years with continuous wild-flood irrigation. The irrigation water ran continually over the meadow from the beginning of the irrigation season until 10 days before harvest.

Vegetative composition studies in a Pinedale native meadow show that sedges and rushes increased, and the grasses, legumes, and forbs decreased with continuous wild-flood irrigation as compared to intermittent irrigation (Fig. 7). In an alsike clover/brome grass mixture the native grasses, sedges and rushes, and clovers increased, and the higher-producing grasses and forbs decreased, with continuous wild-flood irrigation compared with intermittent irrigation. In a complex grass/clover mixture the native grasses and the sedges and rushes increased, the higher-producing grasses and forbs decreased, and the clover showed no change under continuous wild-flood irrigation compared with intermittent irrigation.

Highly profitable increases in hay yields, 2 to 4 tons per acre, have been obtained from nitrogen applications on improved forage meadows with controlled intermittent irrigation. There was, however, practically no response to nitrogen application on meadows where continuous wild-flood irrigation was used. Also under this system of irrigation, the higher-producing species seeded in plowed meadows soon gave way to the more persistent low-yielding native grasses, rushes, and sedges. With continuous wild-flood irrigation, drainage problems develop, and it is impossible to put into practice a good soil-and-moisture conservation program.

Of all production factors studied in the mountain-meadow-improvement research program, proper application of irrigation water is of most importance and in addition is the most challenging to the rancher. Without proper irrigation it is impossible to practice a sound meadow-improvement program that will maintain maximum stands of higher-producing forage species and hay yields over a period of years.
Establishment of Higher-Producing Forage Species

If maximum yields of forage are to be produced, in the majority of the meadow areas it will be necessary to break up the old meadow sod. This will allow for the introduction of higher-producing grass and legume species and, with the control of water, will enable the rancher to maintain them. Research results, as well as practical experience, indicate that it requires from 1 to 3 years for the sod to decompose sufficiently to permit final leveling and seedbed preparation. During this peri-
od it has been found profitable to grow a hay crop of oats or oats and peas. (Fig. 8). This method of land preparation is well adapted where the surface soil is more than 10 inches deep but is less well adapted to shallow soils, which have only 3 to 4 inches of soil overlying unconsolidated gravelly and stony material. The shallow soils haven’t sufficient depth to allow for plowing, disk, and leveling operations. In a few instances, grassland seeders or broadcasting have been effective in introducing new forage species in old meadows located on shallow soil, where the irrigation water has been properly applied and the water table controlled.

Information obtained from the Pine-dale experiments, located on deep sandy loam soil, has been tried on a field-scale basis in meadow areas in various parts of the state. The results from a few of these trials are shown below:

At Daniel a 40-acre meadow located on medium-depth loam soil which had produced 3/4 tons of hay an acre was plowed, disked, leveled, and seeded to a grain in 1951 and to a grass/legume mixture in 1952. Each year following seeding, the field has been irrigated intermittently with the border method. The meadow yielded 3 tons of oat hay per acre in 1951 and averaged 3 tons of grass/legume hay per acre in 1953, 1954, and 1955, and 1 1/2 tons in 1956. The lower yield in 1956 was due to a nitrogen deficiency, which showed up in the grasses for the first time in early July. Nitrogen fertilizer has never been applied on this meadow.

At Boulder, a native meadow, located on Boulder shallow gravelly loam, which had been continuously wild-flooded for years, produced 1/2 ton of hay per acre for several years before 1953. It was plowed, disked, and harrowed in 1953 and seeded to oats and peas in

1954. In 1955 it was again plowed and seeded to a grass/legume mixture, with oats as a nurse crop, and sub-irrigated. It produced 3½ tons of oats-and-pea hay in 1954, 70 bushels of oats seed in 1955, and 4 tons of grass/legume hay in 1956.

Eighty acres of native meadow at Encampment, located on a deep sandy loam soil which had produced 60 tons of hay in 1954, was plowed, disked, and leveled in the fall and seeded to oats the next spring. In 1955 it yielded 120 tons of oat hay. In the spring of 1956 the field was seeded to grass/legume mixture.

Eleven grass species were seeded in a nursery at Pinedale in 1950. With proper irrigation and annual fertilization with 80 pounds of nitrogen per acre, these grasses produced an average of 3½ tons of hay per acre during 1951-1953. Five of these original 11 grass species produced 4.5 tons per acre in 1955 with 80 pounds of nitrogen applied.

A similar experiment was started in 1950 in the Little Laramie River basin near Laramie. However, in this study continuous wild-flood irrigation was used, and the native species crowded out the improved species by 1954. Results from this experiment and other similar ones show that it is useless to seed improved forage species in native meadow areas without a well-planned soil and water-management program.

Research results indicate that the following grasses and legumes are well adapted to the mountain-meadow areas of Wyoming:

**Adapted Grasses**

- Bromegrass
- Intermediate wheatgrass
- Meadow foxtail, orchardgrass
- Reed canarygrass, timothy

**Adapted Legumes**

- Alsike clover
- Red clover
- Alfalfa

Other grasses and legumes which have not been studied as yet may also be found to be adapted.

**Nitrogen Fertilization Shows Promise**

Nitrogen deficiencies have been observed throughout all the mountain-meadow areas of Wyoming. They may be recognized by the short, sparse, yellow appearance of the grasses and also by the clumps of normal growth where animal manure was left undisturbed in the field. (Fig. 9).

Results of 75 trials through Wyoming meadow areas since 1950 show marked increase in hay yields from annual broadcast applications of nitrogen on higher-producing forage species where good soil and water-management practices were used. In contrast there was little or no response to nitrogen on native-sedge-type meadows where continuous wild-flood irrigation was practiced. Results from 14 of these trials on higher-producing grass/clover mixtures with intermittent irrigation show average yields of 3 tons of hay per acre containing 8 percent crude protein from 80 pounds of nitrogen, and average yields of 4.2 tons of hay containing 12 percent crude protein from 160 pounds of nitrogen. This compares with 1 ton containing 7 percent crude protein without applied nitrogen.

Similar experiments on native meadows at 9 locations produced 2 tons of hay per acre containing 8 percent crude protein from 80 pounds of nitrogen and 3 tons containing 11 percent crude protein from 160 pounds. Slightly less
FIG. 9—The tall, dark clumps of grass are the result of manure left undisturbed on the meadow after winter feeding of livestock.

than 1 ton per acre containing 8 percent crude protein was produced without applied nitrogen. In 5 experiments on native-sedge/rush-type meadow, with nitrogen fertilizer applied at rates up to 160 pounds per acre and the meadows irrigated by continuous wild-flooding, all yields were less than 1 ton of hay per acre. The remaining 47 trials were miscellaneous experiments conducted in cooperation with the Wyoming Extension Service at several locations throughout the state. These were on mountain meadows of various types where the irrigation water was fairly well applied and where nitrogen was applied at 80 pounds per acre. In all these trials the increases in hay yields were enough to more than pay for the cost of the nitrogen.

In 1953 a nitrogen fertilizer experiment was started on each of eight higher-producing grass species at Pinedale on a deep, sandy loam soil. The eight grasses were Lincoln, Manchar, and common bromegrass, orchardgrass, timothy, intermediate wheatgrass, meadow foxtail, and reed canarygrass. All these grasses except orchardgrass are well adapted to the Pinedale area. Meadow foxtail reaches maturity about three weeks earlier than the other grasses. The average hay yields for 1953 and 1954 from 0, 80, and 160 pound nitrogen treatments were 0.8, 2.9, and 3.7 tons per acre respectively (Fig. 10). The respective crude-protein yields from these treatments were 122, 508, and 919 pounds per acre. The forage from the zero nitrogen treatment contained 7.6

![Diagram](image-url)

**FIG. 11**—Effect of time of cutting and of nitrogen applications upon average forage yields of five grasses on a deep sandy loam soil at Pinedale in 1955. (Yields include first cut plus aftermath.)
FIG. 12—Effect of time of cutting and of nitrogen applications upon crude-protein yield of five grasses grown on a deep sandy loam soil at Pinedale in 1955. (Yields include first cut plus aftermath.)

FIG. 13—Effect of time of cutting and of nitrogen applications upon average crude-protein percentage in first-cut forage of five grasses grown on a deep sandy loam soil at Pinedale in 1955.
FIG. 14—Effect of nitrogen applications upon average crude-protein percentage of aftermath forage of five grasses after different times of cutting at Pinedale in 1955.

percent crude protein compared with 12.4 percent for the 160 pound treatment.

Response from phosphorus has been quite erratic compared with that received from nitrogen. Phosphorus has been found to increase population and yields of legumes in certain locations. At Crowheart and Saratoga, increases in yield of 2 to 3 tons per acre were obtained from applications of phosphorus in alfalfa. No response to phosphorus has been measured in forage yields from any grass species. Potash has been applied to forage crops in several mountain-meadow areas of Wyoming without response at any location.

**Time of Harvest Important**

In 1955 an experiment was conducted at Pinedale on a deep sandy loam soil to study the effect of time of harvest and rate of nitrogen fertilization upon the total forage and crude-protein yield of 5 higher-producing grass species. The five grasses were Manchar brome grass, timothy, intermediate wheatgrass, meadow foxtail, and reed canarygrass. Forage yields increased with each delay in harvest date of each nitrogen rate except for the no-nitrogen treatment (Fig. 11). The yields from this treatment increased with each delay in harvest up to the August 5 cutting date, then decreased at the August 22 cutting. The total crude protein yield was about equal for the first, second, and third dates but was considerably reduced at the 4th cutting date of each nitrogen rate (Fig. 12). There was, however, a consistent decrease in the crude-protein percentage of the forage from the first to the last harvest date of all nitrogen rates (Fig. 13). The crude-protein percentage of the aftermath forage harvested after the first and second cutting dates was higher than that of the forage harvested after the August 5 cutting date at all nitrogen rates (Fig. 14).

Nitrogen applications increased total hay and crude-protein yields and crude-protein percentage of hay and aftermath forage at all harvest dates. The highest yield of hay occurred at the last
cutting date, which approximates the mature-seed stage of growth. The highest yield of crude-protein occurred at the third harvest date, which approximates the soft-dough stage of growth. The highest crude-protein percentage of the first-cut hay and aftermath occurred in the earlier cuttings.

To obtain maximum yield of high-protein hay, the higher-producing grass-forage species should be cut at soft-dough stage of growth. Late-cut hay becomes coarse, unpalatable, and low in protein. Further decisions on when to cut hay depend upon feed requirement, time, and equipment available.

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