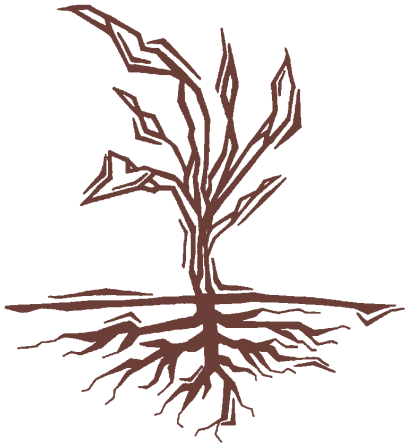

SOIL

Fertilizing Mountain Meadows no. 0.535

by J.J. Mortvedt, D.H. Smith and J.E. Brummer [1]

Quick Facts...

Nitrogen can be applied in the fall or spring depending on use of the meadow and goals of the producer, especially concerning grazing.

Apply nitrogen fertilizers to irrigated mountain meadows on the basis of yield potential. Spring application usually is more effective than fall application.

Apply phosphate fertilizers on the basis of soil test results. Topdress phosphate fertilizers in the fall.

Most Colorado soils contain sufficient available potassium and sulfur for forage production. However, these nutrients may become limiting through nutrient removal by hay.

Colorado State University Cooperative Extension

Putting Knowledge to Work

Mountain meadows supply the forage base for year-round livestock production in the Rocky Mountain region. Hay yields from mountain meadows average about 1.3 tons per acre. Low soil fertility generally is the major factor limiting forage production, with nitrogen (N) being the most limiting nutrient. Use of N fertilizers is the fastest, most economical way to increase forage production on irrigated mountain meadows. However, meadows dominated by organic soils that are flooded during part of the growing season may have lower responses to N fertilization than meadows dominated by mineral soils. Therefore, soil type must be considered when determining N management and the profitability of a N fertilization program.

Phosphorus (P) is the second most limiting nutrient for forage production, while potassium (K) and sulfur (S) usually are not limiting. However, these nutrients may become limiting as nutrient removal continues through annual harvesting, especially on highly productive soils. Before establishing a stand, test soils to determine their fertility status so appropriate fertilizers can be applied and properly incorporated.

Do not apply fertilizers immediately adjacent to streams or other surface waters to prevent possible water contamination.

For more information on fertility requirements and cultural practices for mountain meadows, refer to "Nitrogen Fertilization of Mountain Meadows," *J. Prod. Agr.* 8:239-243 (1995).

Soil Sampling

The value of a soil test in predicting nutrient availability during the growing season is directly related to how well the soil sample collected represents the area sampled. Take surface samples from the 1-foot soil depth. A good sample is a composite of 15 to 20 soil cores taken from a uniform soil type. Sample separately areas with major differences in soil properties or management practices.

Thoroughly dry all samples within 12 hours after sampling by spreading the soil on clean paper or any other clean surface where the soil will not be contaminated. **Do not oven dry the soil** because this will change the test results. Ship the air-dried soil in a clean sample container to the soil test laboratory.

Submit a carefully completed information sheet with the soil sample. This form provides information so fertilizer application suggestions can be tailored to each specific situation. For existing stands, periodically test soils for nutrient analysis for optimum nutrition.

More detailed explanations of the importance of taking proper soil samples are found in 0.500, *Soil Sampling*, 0.501 *Soil Testing*, and 0.502 *Soil Test Explanation*. These fact sheets are available at your Colorado State University Cooperative Extension county office or from the Cooperative Extension Resource

Center, 115 General Services Building, Colorado State University, Fort Collins, CO 80523; (970) 491-6198.

The Colorado State University Soil, Water and Plant Testing Laboratory is located in Room A319, Natural and Environmental Sciences Building, Colorado State University, Fort Collins, CO 80523; (970) 491-5061.

Nitrogen Suggestions

Mineral Soils

Forage response to N fertilizer can vary significantly, depending on N source and time of application. Table 1 shows yield responses to various rates of ammonium nitrate or urea applied in the spring or fall on a mineral soil. Yield increased significantly up to the 150 lb N/A rate, which is typical for most mountain meadows. Both the recovery of fertilizer N as crude protein in the forage and efficiency of fertilizer N (pounds of forage per pound of N fertilizer) tend to decrease at rates above 150 to 160 lb of N/A. On mineral soils, recovery of applied N in the forage generally ranges between 30 and 50 percent, but may be as high as 80 percent. Fertilizer N efficiencies for the study in Table 1 ranged between 23 and 44 pounds of forage per pound of N applied as ammonium nitrate, and 18 to 36 pounds of forage per pound of N applied as urea. These ranges are typical for mineral soils, with the lowest N rates having the highest efficiencies.

Relative effectiveness of the various N fertilizer sources is of concern to forage producers. Granular urea and ammonium nitrate, and urea-ammonium nitrate solution are the main N sources. Research has shown that N losses from ammonia volatilization from urea-based fertilizers may be of practical significance when the soil pH is greater than 7.0. Surface application of these fertilizers on high-pH soils with significant amounts of plant residues increases the potential for ammonia loss.

Table 1: Effects of nitrogen rates, sources and time of application on yield of irrigated mountain meadow hay located on a mineral soil (3-year averages) (Follett et al., 1995).

N rate,	Ammonium nitrate		Urea	
lb/A	Fall	Spring	Fall	Spring
	----- Yield, tons/A -----			
0	1.1	1.1	1.1	1.1
50	2.2	2.2	1.9	2.0
100	2.8	3.1	2.6	2.6
150	3.4	3.4	2.9	2.8
200	3.4	3.4	2.9	3.1

Table 1 shows higher hay yields with ammonium nitrate than urea for either fall or spring applications. However, other research results on mountain meadows located on mineral soils generally have shown that differences in yields and total N uptake among N sources have not been significant. Rate of N application usually has a greater effect than N source under these conditions.

Spring applications of N fertilizers sometimes produce higher forage yields and protein content of hay than fall applications. However, spring applications may not be possible for meadows that are very wet in the spring. For fall N applications, ammonium nitrate is preferred over urea because yield response and recovery of N fertilizer generally are higher with ammonium nitrate. Nitrogen fertilizers must be applied annually for optimum forage production.

Preplant N fertilizers generally are applied broadcast and incorporated in combination with P fertilizers. Application of N fertilizers to mountain meadows is not suggested under dryland conditions.

Organic Soils

Many mountain meadow soils have developed a dense surface mat of organic matter that ranges from 1 to 4 inches thick. This mat (often referred to as a peat layer) has developed as the result of many years of flood irrigation with cold water from snowmelt. These organic mats contain large amounts of nutrients, the majority of which are not available for plant uptake.

Nitrogen fertilizer applications usually increase forage production on meadow soils with organic mats. However, recovery in the forage and use efficiency of the applied N generally are much lower on organic soils than on mineral soils. Fertilizer N recovery generally averages less than 30 percent on

Table 2: Effects of nitrogen rates on yield, fertilizer nitrogen efficiency, crude protein, and fertilizer nitrogen recovery on an irrigated mountain meadow located on an organic soil (Ludwig and Rumburg, 1975).

N rate lb/A	Yield tons/A	Fertilizer N efficiency, lb forage/ lb N	Crude protein %	Crude protein lb/A	Apparent fertilizer N recovery, %
0	2.67	---	5.9	315	---
60	3.26	19.7	6.0	391	18.5
120	3.71	17.3	6.3	467	20.2
180	4.06	15.4	6.5	528	19.0
240	3.84	9.8	7.1	545	15.0

organic soils. Fertilizer N efficiency averages about 20 pounds of forage per pound of N at application rates between 60 and 100 lb N/A. However, efficiencies between 8 and 12 pounds of forage per pound of N are not uncommon, depending on individual site characteristics. Table 2 shows yield responses and fertilizer N efficiency on a mountain meadow located on a poorly drained and excessively wet organic soil (13 percent organic matter). Forage yields increased from 2.67 to 4.06 tons/A with 180 lb of N/A. Crude protein also increased with N rate. Although yield response was good at this location, fertilizer N recovery as crude protein in the forage averaged only 18 percent on this organic soil, as compared with 30 to 50 percent on mineral soils.

The waterlogged soil conditions associated with flood irrigation practices common in mountain meadow areas can lead to low fertilizer N use efficiency. The lack of oxygen in waterlogged soils leads to denitrification, which converts various soil N sources into gaseous forms that escape to the atmosphere.

Nitrogen fertilization also can stimulate an increase in microbial activity in these organic soils. This can immobilize considerable amounts of applied N as microbial biomass, which decreases fertilizer N efficiency. Producer experience indicates that forage yields may actually decline for several years following cessation of a N fertilization program on organic meadow soils. Nitrogen probably is being tied up by soil microbes as the result of the artificially induced imbalance in the soil carbon to nitrogen ratio. Based on these observations, once a N fertilization program is initiated on organic soils, it is wise to continue N applications without interruption.

Although organic soils respond favorably to N fertilization, the lower rate of N recovery must be considered when determining optimum N rates based on economic returns. Nitrogen fertilization of organic meadow soils generally is economically feasible, but break-even values will be lower as compared with those for mineral soils. Economic increases in forage production generally can be obtained when N is applied to organic soils at rates between 60 and 100 lb of N/A. However, the safest approach for producers with organic soils may be to apply N on small test strips in their meadows, because the variability in response among locations makes it difficult to give general application recommendations.

Special Nitrogen Management Considerations

Fall applications of N fertilizers can produce hay yields equal to or greater than spring applications, depending on species present and if appropriate application timing is used. Research shows that meadows, especially those with a high proportion of smooth bromegrass, can produce significantly higher yields of hay if fertilized in the fall. Applying N in the fall stimulates smooth bromegrass plants to set more reproductive tillers which translate to higher yields the next summer. One must keep in mind that although higher yields are possible, quality (crude protein content and digestibility) of that forage may be lower due to the higher fiber content of reproductive grass tillers.

Timing of fall N applications is also an important consideration to achieve the maximum benefit of the fertilizer, regardless of the grass species present in the meadow. Applying N too early in the fall allows grass plants time to take up some of the N and translocate it into aboveground tissues. This N is then tied up in the litter component when the plant eventually goes dormant in the fall which makes it unavailable for growth in the spring. Ideally, N fertilizers should be applied to mountain meadows early enough in the fall to allow uptake by the roots, but later enough so the N does not get translocated into

the aboveground leaves of the plant. For most higher elevation meadows, fall application of N fertilizers should take place after the first frost of October and before the ground freezes for maximum efficiency.

A final consideration of whether to apply N fertilizers in the fall or the spring concerns the grazing practices on a given meadow. If the meadow will be grazed in the spring and the ultimate goal is hay production, then the meadow should not be fertilized in the fall. Grass plants are sponges for N and they will quickly take up any available N in the spring that was applied in the fall and translocate it into aboveground leaves. As animals graze the leaves off in the spring, they remove significant amounts of the applied N thereby reducing fertilizer efficiencies and subsequent hay yields later in the summer. Similarly, N fertilizers should not be applied too early in the spring if the meadow will be grazed. Given adequate moisture, it takes as little as 10 to 14 days for a considerable amount of spring applied N to be translocated into the leaves where it can be grazed off by livestock. On the other hand, if the goal is to produce forage for spring grazing, then fall or early spring applications of N can be used as tools to increase forage yields.

Table 3: Suggested broadcast phosphorus rates for irrigated mountain meadows.

ppm P in soil		Relative	Fertilizer rate, lb P_2O_5/A	
AB-DTPA	$NaHCO_3$	level	New seedings	Established stands
0 - 3	0 - 6	very low	80	40
4 - 7	7 - 14	low	40	20
8 - 11	15 - 22	medium	20	10
> 11	> 22	high	0	0

NOTE: Apply P fertilizers for established stands on the basis of new soil test results.

Table 4: Suggested broadcast potassium rates for irrigated mountain meadows.

ppm K in soil AB-DTP or NH_4OAc	Relative level	Fertilizer rate, lb K_2O/A
0 - 60	low	60
60 - 120	medium	40
> 120	high	0

Phosphorus Suggestions

Forage responses to applied P are most likely on soils with low or medium levels of extractable P. Suggested P rates (Table 3) are based on broadcast applications related to soil test levels. The main soil tests for extractable P in Colorado soils are the AB-DTPA and sodium bicarbonate ($NaHCO_3$) tests, and values for both tests are included.

Table 3 suggests P rates for establishing irrigated meadows for forage production. Take soil samples prior to seedling establishment. Broadcast and incorporate phosphate fertilizers into the soil prior to seeding.

Established meadows should be topdressed periodically with phosphate fertilizers to help maintain stands, especially if legumes are present. For established stands, apply P fertilizers on the basis of new soil test levels, but use about half of the rates suggested for new seedings. Test soils in the early fall so P fertilizers may be topdressed in the fall, if needed. While P does not move in soil under most conditions, phosphate fertilizers may be washed into cracks in dry soil during the fall and spring, or be incorporated by freezing and thawing during the winter months. Branch roots near the soil surface also may take up applied fertilizer P.

Because P is not susceptible to leaching losses, it can be applied once every 2 to 3 years at higher rates to avoid yearly applications costs. The probability of forage response to topdressed P is greater on soils testing very low to low in extractable P.

Placement of P fertilizers in the root zone is important because P is not mobile in soil. Broadcast application followed by incorporation prior to planting is the most efficient placement method for P.

Most phosphate fertilizers are equally effective per unit of P. Choose a fertilizer based on availability and cost per unit of P.

Potassium Suggestions

Most Colorado soils are relatively high in extractable K, and few forage responses to K fertilizers have been reported. Table 4 suggests rates related to soil test values (AB-DTPA or NH_4OAc). The main K fertilizer is KCl (potash).

Broadcast application incorporated into the soil prior to planting is the usual method. Potassium fertilizers may be topdressed on established meadows to help maintain stands, especially if legumes are present.

Sulfur Suggestions

Sulfur is a key component of protein, and demand for S increases as forage yields increase. Adequate S is required for optimum N-use efficiency, so S nutrition should not be overlooked in forage management. Poor S nutrition can lead to low plant protein content and digestibility in forages. Several fertilizer sources are available to supplement S needs of crops.

Most Colorado soils contain adequate levels of available S, and soil tests for available S are not routinely performed. Irrigation water from most surface waters and some wells often contains appreciable SO_4-S, so irrigated soils usually are adequately supplied with S. However, some well waters are low in SO_4-S, so water samples should be analyzed if soils are low in organic matter and S deficiency is suspected.

Other Nutrients

There have been no confirmed deficiencies of boron (B), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) in mountain meadows for forage production in Colorado.

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