A2448

Alfalfa fertilization

K.A. Kelling

Modern management of alfalfa uses improved varieties, intensive harvest schedules, direct seeding, and up-to-date fertilization practices. Due to high production costs and narrow profit margins, appropriate use of lime and fertilizer is more important today than ever before.

Alfalfa has long been noted as a soil builder. Its ability to fix atmospheric nitrogen and improve soil structure is well known. However, as shown in table 1, alfalfa can rapidly deplete the soil of phosphorus, potassium, and other nutrients. Data from Wisconsin and other Midwestern states indicate that each ton of alfalfa harvested removes about 14 pounds of phosphate (P_2O_5) and 60 pounds of potash (K_2O). This is about the nutrient equivalent of 150 pounds of a 0-10-40 fertilizer. Each ton of alfalfa also removes the calcium and magnesium equivalent of about 100 pounds of aglime. Another 62 pounds of aglime would be required to replace the liming equivalent represented by the potassium in 1 ton of alfalfa. These nutrients must be supplied either from the native soil reserves or through liming and fertilization.

Table 1. Pounds of nutrient removed per ton of alfalfa, dry matter basis.

Nutrient	alfalfa dry matter (lb/ton)
Phosphorus*	6
Potassium*	49
Calcium	30
Magnesium	6
Sulfur	6
Boron	0.08
Zinc	0.05
Manganese	0.12
Copper	0.01
Iron	0.33
Molybdenum	0.002

*Plants may remove higher amounts of these nutrients if soil test levels are in the high or excessively high range.

Assessing soil nutrient needs

There are three ways to determine whether the soil has sufficient nutrients for the plants: through soil testing, through interpretation of visual symptoms exhibited by the growing plant, or through plant tissue analysis.

Soil testing is the most convenient and economical method of evaluating the fertility levels of a soil. It is the only diagnostic method that predicts nutrient needs before the crop is planted. The optimal Wisconsin soil test levels for alfalfa are shown in table 2. Soil sampling procedures are outlined in Extension publication *Sampling Soils for Testing* (A2100), available from your county Extension office. For detailed information on soil test recommendations, refer to Extension publication *Soil Test Recommendations for Field, Vegetable, and Fruit Crops* (A2809).

Table 2. Optimum Wisconsin soil test levels for alfalfa.

Soil test	Sandy soils	Medium-textured soils: Southern & western	Medium-textured soils: Northern & eastern red	Medium-textured soils: Northern
	ppm			
Soil pH	6.8	6.8	6.8	6.8
Available phosphorus	26–37	16–23	18–25	16–23
Exchangeable potassium	81–120	91–120	71–100	111–140
Calcium	401–600	601–1000	601–1000	601–1000
Magnesium	51–250	101–500	101–500	101–500
Boron	0.5–1.0	0.9–1.5	0.9–1.5	0.9–1.5
Sulfur (SAI)*	30–40	30–40	30–40	30–40

*Sulfur availability index combines soil test sulfur with estimates of available sulfur from organic matter, precipitation, and the subsoil, and indicated manure applications.

Table 3. Visual nutrient deficiency symptoms for alfalfa.

Nutrient	Deficiency symptoms
Nitrogen	Stunted or spindly growth; light green to yellow color.
Phosphorus	Blue-green or dark colored leaves, especially on acid soils; stunted, stiff, or erect growth. Leaflets often fold together, and the undersides and stems may be red or purplish.
Potassium	White spots around edge of leaves. Spots begin on lower leaves but are most obvious on upper leaves. In advanced cases leaves turn completely yellow and drop off.
Calcium	Impaired root growth or rotting. Petioles collapse on youngest mature leaves.
Magnesium	Interveinal chlorosis of lower leaves, margins initially remain green.
Sulfur	Overall light green color; somewhat similar to nitrogen deficiency; spindly stems and weak growth.
Boron	Yellow or reddish-yellow upper leaves; plant top may appear bunched with short internodes; can be confused with leafhopper damage. In advanced cases leaves may turn bronze color and the growing point may die.
Manganese	Interveinal chlorosis of younger leaves.
Iron	Interveinal chlorosis of youngest leaves, bleached appearance.
Zinc	Small leaves; youngest leaves curl upward.
Copper	Severe curvature of petioles, grayish spots in midleaf.
Molybdenum	Pale green and stunted as with nitrogen deficiency.

Visual deficiency symptoms will reveal nutrient problems that arise during the growing season. By the time symptoms appear, however, the problem may be severe and significant yield losses may have been experienced. Table 3 describes the appearance of nutrient-deficient alfalfa.

Tissue analysis can determine the nutritional status of your crop possibly before any visual symptoms appear. For some nutrients such as sulfur and many of the micronutrients, this is the best method for determining fertilizer needs. For a more comprehensive nutrient management interpretation, include a soil sample with the tissue sample. The sufficiency levels for the essential nutrients in alfalfa plant tissue currently being used by the University of Wisconsin are shown in table 4. More detailed information on taking and submitting plant analysis samples is presented in Extension publication *Sampling for Plant Analysis* (A2289).

Liming program

Proper soil pH affects all phases of alfalfa growth—from establishment, disease resistance, top yields, and improved quality, to winter hardiness and stand survival. Economic analyses indicate that it is most profitable to lime soils planted to alfalfa to a pH of 6.8–7.0. Lime requirements are determined by a soil test. In fields where lime is needed, the first dollars spent for alfalfa fertility programs should be for lime. No other practice will improve alfalfa production potential as much. For maximum benefit, lime should be well mixed throughout the plow layer at least 6 months, and preferably a year or more, before seeding.

There has been an ongoing debate about the best type of lime to apply. Some people advocate the use of calcitic limestone over the locally available, less-expensive dolomitic lime. They claim that there is an ideal soil calcium to magnesium ratio for optimum plant growth and

Table 4. Sufficiency levels of nutrients in the top 6 inches of alfalfa.

Nutrient	Low	Sufficient	High
		%	
Nitrogen (N)	<2.50	2.50–4.00	>4.00
Phosphorus (P)	<0.25	0.25–0.45	>0.45
Potassium (K)	<2.25	2.25–3.40	>3.40
Calcium (Ca)	<0.70	0.70–2.50	>2.50
Magnesium (Mg)	<0.25	0.25–0.70	>0.70
Sulfur (S)	<0.25	0.25–0.50	>0.50
		ppm	
Zinc (Zn)	<20.0	20.0–60.0	>60.0
Boron (B)	<25.0	25.0–60.0	>60.0
Manganese (Mn)	<20.0	20.0–100.0	>100.0
Iron (Fe)	<30.0	30.0–250.0	>250.0
Copper (Cu)	<3.0	3.0–30.0	>30.0

that Wisconsin soils contain too much magnesium for the amount of calcium present. University research has shown not only that the ratio does not affect plant growth when soil pH is kept in the optimal range, but also that virtually all Wisconsin soils have calcium to magnesium ratios within the optimal range. Furthermore, Wisconsin dolomitic limestone itself has a calcium to magnesium ratio within the normal range for plant growth. Choice of liming materials should be based on cost per unit of effective lime, not on their effects on changing the calcium to magnesium ratio. If you'd like more background on this topic, refer to Extension publication *Soil Calcium to Magnesium Ratios—Should You Be Concerned?* (A2986).

Nutrient management

Establishment

Tillage prior to establishment provides the last opportunity to incorporate relatively immobile nutrients during the life of the stand. Incorporating immobile nutrients significantly improves their effectiveness. Nutrients such as nitrogen, phosphorus, potassium, and sulfur, as well as the recyclable nutrients from manure can be added at this time.

Table 5. Recommended rates of annual topdressing of phosphate and potash for alfalfa grown at various soil test levels.

	Soil test interpretation					
Yield goal (tons/a)	**Very low[a]**	**Low[a]**	**Optimum**	**High**	**Very high**	**Excessively high**
	amount to apply, lb/a					
Recommended phosphate (P_2O_5)						
1.5–2.5	65	55	25	10	—	0
2.6–3.5	75	65	35	15	—	0
3.6–4.5	90	80	50	25	—	0
4.6–5.5	105	95	65	30	—	0
5.6–6.5	115	105	75	35	—	0
6.6–7.5	130	115	90	45	—	0
Recommended potash[b] (K_2O)						
1.5–2.5	140	130	100	50	25	0
2.6–3.5	190	180	150	75	40	0
3.6–4.5	240	230	200	100	50	0
4.6–5.5	290	280	250	125	60	0
5.6–6.5	340	330	300	150	75	0
6.6–7.5	390	380	350	175	90	0

[a]Slightly more or less (5–10 lb/a) phosphate and/or potash may be recommended on some soil types.

[b]If the alfalfa stand will be maintained for more than 3 years, increase topdressed potash by 20%.

Adequate soil phosphorus levels increase seeding success by encouraging root growth. Phosphorus is very immobile in most soils. Wisconsin research confirms that at low to medium soil test levels incorporated phosphorus is more than twice as efficient as topdressed phosphorus. For example, when phosphate was plowed down at the rate of 40 lb/a before seeding and the same amount was topdressed the following year, yields were 3.9 tons/a—the same yield as when double the rate (80 lb/a) was topdressed for each of 2 years.

Although potassium has relatively little influence on improving stand establishment, yield and stand survival are highly dependent on an adequate potassium supply. When soil tests are in the optimum range or below, sufficient potassium should be added to meet the needs of the seeding-year crop including the companion crop. As with phosphorus, incorporating potassium significantly increases its efficiency. In trials, plowing down 240 lb/a of potash before seeding and topdressing 240 lb/a the following year produced yields that were ⅓ ton greater than topdressing 480 lb/a of potash for each of the 2 years.

Elemental sulfur, where needed, can be used as the sulfur source and may be applied prior to seeding. Elemental sulfur must be converted to sulfate-sulfur before it can be used by plants. This process is relatively slow—especially when sulfur is topdressed. Therefore, incorporating moderately high rates (50 lb/a) of elemental sulfur at establishment will usually satisfy alfalfa sulfur requirements for the life of the stand. The cost of this treatment should be compared to the cost of annual topdressed applications of sulfate-sulfur.

Recent research has shown that small additions of nitrogen may enhance establishment and first-year yields on sandy soils with low organic matter. Apply 25–30 lb/a nitrogen when alfalfa is direct seeded on coarse-textured soils with less than 2% organic matter. Apply 20–35 lb/a nitrogen when seeding alfalfa with a companion crop or 40–55 lb/a nitrogen if you will be harvesting the companion crop as silage.

Manure may be successfully applied prior to alfalfa establishment if adequate weed control practices are followed. Recent Minnesota and Wisconsin research has shown that preplant manure application can maintain or even increase yields the first 2 years. When spreading manure, avoid compacting soil and incorporate it well so that seed is not planted directly into concentrated bands of manure.

Production

When soil tests are in the high range or below, an annual topdressing is the most cost-effective way to supply needed nutrients. Table 5 shows the rates of phosphate and potash recommended for the major alfalfa growing soils of Wisconsin. Fertilizer recommendations are based on results of the soil test. Soils testing in the following categories for a given nutrient receive the following adjustments to the rates:

Optimum range—recommended rates of fertilizer are equal to anticipated crop removals.

High range—the recommendation drops to half that of the anticipated removal.

Excessively high range—no fertilizer is recommended if soils test excessively high for a nutrient.

The recommendations are designed to keep nutrient levels from falling below the optimal range during 4 years of cropping.

It's important to sharply reduce or eliminate topdressing on soils testing excessively high since excess phosphorus may lead to increased phosphorus in runoff water and excess potassium creates difficult ration balancing problems. Research shows alfalfa potassium levels of greater than 4% when topdressed

potash is applied to soils already testing excessively high. These levels are particularly a problem for dry cows and for heifers late in pregnancy.

Research has shown that in northern Wisconsin higher soil test levels are necessary to get adequate nutrients into the plant. This is built into the recommendation system.

Guidelines for annual topdress applications:

1. Fertilize immediately after harvest and before regrowth resumes. Avoid fertilizer contact with wet foliage.
2. Topdress following first cutting to stimulate second and third cutting regrowth or topdress in early September to increase winter hardiness.
3. Avoid topdressing plants when soils are soft (such as early spring) as physical damage to the alfalfa crown is likely.
4. Split the application to avoid salt damage if using more than 500 lb/a of fertilizer material (irrespective of grade) in any year.
5. Base fertilizer purchases on cost per unit of plant food provided and need for all nutrients contained in the fertilizer. For example, since there is no difference in nutrient availability with red versus white potash or with ortho- versus polyphosphate on most soils, the best choice is the least expensive product per unit of plant food provided.
6. Do not use foliar treatments to apply moderate to high rates of macronutrients as salt damage may occur and nutrient uptake is not enhanced. Foliar treatments are, however, an excellent method for applying micronutrients.

Fertilizer recommendations

Nitrogen—Apply 25–30 lb/a nitrogen prior to seeding on sandy, low organic matter (<2%) soils. Research shows that on established stands that are well limed and inoculated, nitrogen applications do not increase yields or protein content. Adding nitrogen may lower yield and/or quality by stimulating weed growth. Some nitrogen may also be warranted on grassy stands or stands that have not been adequately limed.

Phosphorus—Apply the recommended amount of phosphorus prior to seeding. Phosphorus is more effective when it is plowed down before seeding than when it is topdressed. However, where needed, topdressing can be a satisfactory application method.

Potassium—On soils testing low for potassium, apply potash before seeding. Topdress annually after the first or third cutting according to soil test recommendations. Annual topdressings at the recommended rate reduce the likelihood of luxury consumption and excessive forage potassium levels.

Calcium and magnesium—If needed, apply calcium and magnesium as aglime prior to seeding. Aglime additions are usually effective for 6–8 years. Recommendations for supplemental calcium on well-limed soils have not been supported by University of Wisconsin research. Repeated high potassium additions may cause magnesium deficiency on low exchange capacity soils.

Sulfur—Sulfur may be needed on sandy soils or on shallow, medium-textured soils in northern Wisconsin that have not received manure in the last 2 years. Sulfur can be added before seeding as either elemental sulfur (S) or sulfate (SO_4). Fertilization with 25–50 lb/a sulfate-sulfur is adequate for at least 2 years in most cases. Sulfur is usually topdressed as potassium sulfate, gypsum, or potassium-magnesium sulfate. Correcting a sulfur-deficient soil can increase yields by up to 1 ton/a.

Boron—On medium-textured soils, apply boron once in the rotation at a rate of 2–3 lb/a. On sandy soils apply 0.5–1 lb/a of boron each year. Usually boron is mixed with another fertilizer such as 0-0-60. Do not apply boron near germinating seeds.

Manganese, zinc, iron, and copper—Routine applications of these micronutrients are not recommended since deficiencies in alfalfa are rare in Wisconsin. If you suspect a deficiency, confirm the problem through plant analysis before treating.

Manure—Manure is an excellent source of nitrogen, phosphorus, sulfur, and boron, and often contains barn lime. Manure may be safely applied at relatively high rates prior to stand establishment. Manure should not be applied to established alfalfa hay ground if other fields are available. The manure stimulates grass production and weed growth, results in lower protein forage, and tends to reduce the alfalfa stand. If you must topdress manure on established alfalfa, select fields that have the most grass in them and that have relatively low phosphorus and potassium levels. Spread manure at relatively low rates (i.e., 10 tons/a or 3000–5000 gal/a) as soon as possible after the forage is off the field.

Related publications

Sampling for Plant Analysis (A2289)

Sampling Soils for Testing (A2100)

Soil Test Recommendations for Field, Vegetable, and Fruit Crops (A2809)

Understanding Plant Nutrients (series)

- Soil and Applied Boron (A2522)
- Soil and Applied Calcium (A2523)
- Soil and Applied Chlorine (A3556)
- Soil and Applied Copper (A2527)
- Soil and Applied Iron (A3554)
- Soil and Applied Magnesium (A2524)
- Soil and Applied Manganese (A2526)
- Soil and Applied Molybdenum (A3555)
- Soil and Applied Nitrogen (A2519)
- Soil and Applied Phosphorus (A2520)
- Soil and Applied Potassium (A2521)
- Soil and Applied Sulfur (A2525)
- Soil and Applied Zinc (A2528)

Author: K.A. Kelling is professor of soil science, College of Agricultural and Life Sciences, University of Wisconsin-Madison and University of Wisconsin-Extension, Cooperative Extension. Produced by Cooperative Extension Publishing.

University of Wisconsin-Extension, Cooperative Extension, in cooperation with the U.S. Department of Agriculture and Wisconsin counties, publishes this information to further the purpose of the May 8 and June 30, 1914 Acts of Congress; and provides equal opportunities and affirmative action in employment and programming. If you need this material in an alternative format, contact the Office of Equal Opportunity and Diversity Programs or call Cooperative Extension Publishing at 608-262-2655.

This publication is available from your Wisconsin county Extension office or from Cooperative Extension Publishing, 45 North Charter Street, Madison, WI 53715, 608-262-3346. Outside Madison, call our toll-free number: 877-WIS-PUBS (947-7827). Before publicizing, please check on this publication's availability. To see more Extension publications, visit our web site at www.uwex.edu/ces/pubs/.

A2448 Alfalfa Fertilization R-11-00-1.5M-100