UNDERSTANDING MICRONUTRIENT FERTILIZATION IN ALFALFA

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ABSTRACT

Alfalfa is the major forage used for feed in the dairy and other animal industries in California and the Western United States. It is grown on approximately ten percent of the irrigated acreage in California and is a major forage crop in many other states. Fertilizers and certain waste materials like fly ash and animal manures can be valuable resources in the production of alfalfa and a number of forage crops. Many, including alfalfa require large quantities of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur and, the micronutrients in smaller amounts. This presentation will focus on the secondary nutrient sulfur and the micronutrients boron and molybdenum as they influence the growth of alfalfa and other forages. Methods that can be utilized by growers and others to evaluate the need for fertilizer nutrient additions will be discussed along with their relative effectiveness in diagnosing alfalfa growth problems.

Key Words: alfalfa, sulfur, micronutrients: boron, molybdenum, copper, iron, zinc, manganese, chlorine, hay quality, nutrient uptake

INTRODUCTION

Providing an adequate supply of nutrients for alfalfa and other forages is essential to maintaining high and profitable yields. However, proper plant nutrition can be a complex and often difficult management process. The process includes an analysis of which nutrients are needed, selection of the proper fertilizer, application amount, timing and placement, economics, record keeping, and environmental considerations. Before applying fertilizer to alfalfa, examine other factors affecting yield. It makes little sense to fertilize with a nutrient when another factor is more limiting to plant growth. For example, an application of sulfur, even when sulfur is deficient, may not increase yields if water is not sufficient to allow plants to grow in response to applied fertilizer. Since historical trends help with management decisions, thorough, well-organized records of plant tissue and soil-test information are important. Records should include information about date of sampling; crop yields and fertilizer application history; and, most importantly, the location of where the samples were taken. Global Positioning Systems (GPS) can be used to draw very detailed farm maps or even the handheld units can easily be used to locate and then later relocate where soil and plant tissue samples were taken. This presentation serves as a guide to alfalfa fertilization with micronutrients and includes information on methods that can be used to determine when alfalfa may respond to there addition.

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ESSENTIAL PLANT NUTRIENTS

Seventeen elements are needed, in varying amounts, for plant growth. Carbon, hydrogen, and oxygen come from water and from carbon dioxide in the air. The other 14 elements are obtained from either the soil or fixation of atmospheric nitrogen by bacteria in root nodules. Another nutrient, cobalt, is essential to legumes, for nitrogen fixation. Growth slows or stops when a plant is unable to obtain one or more of these elements. Thus, all nutrients must be available to the plant in adequate quantities throughout the production season. The nutrients that are most commonly needed are phosphorus, potassium, sulfur, boron, and molybdenum (Table 1).

Table 1. Secondary and micronutrient needs of alfalfa and an estimate of fertilizer needs in the Western U. S.

Element Needed	Symbol	Fertilizer Required[1]
Calcium	Ca	Never
Magnesium	Mg	Never
Sulfur	S	Infrequently
Iron	Fe	Seldom
Manganese	Mn	Never
Chlorine	Cl	Never
Boron	B	Infrequently
Zinc	Zn	Never
Copper	Cu	Never
Molybdenum	Mo	Infrequently
Nickel	Ni	Never
Cobalt[2]	Co	Never

[1] Infrequently: Less than 20% of the acreage shows need for fertilization.
Seldom: Less than 1% of the acreage shows need.
Never: A deficiency has never been observed or documented. Deficiencies in other crops generally occur at <20 ppm “active” Fe, at <15 ppm total Mn, at <15 ppm total Zn, at <3 ppm total Cu and <0.1 ppm total Co.

[2] Necessary for nitrogen fixation only.

DIAGNOSIS OF NUTRIENT DEFICIENCIES

A key aspect of designing a fertilization program is evaluating the nutrition status of the alfalfa. This can be done by visual observation, soil analysis, or plant tissue testing. Using all three in combination provides the best results.

Visual Observation

Nutrient deficiencies may exhibit visual plant symptoms such as obvious plant stunting or yellowing. Table 2 summarizes visual symptoms of common deficiencies. Unfortunately, visual symptoms are not definitive and can be easily confused or mistaken for symptoms caused by other factors—insect injury, diseases, and restricted root growth. The other problem with using visual observation of plant symptoms to diagnose nutrient deficiencies is that significant yield losses may have already occurred by the time the symptoms appear. Always confirm visual diagnosis with laboratory diagnosis or test strips with selected fertilizers.

Table 2. Secondary and micronutrient deficiency symptoms observed in alfalfa.

Deficiency	Symptoms
Sulfur	Generally yellow, stunted plants
Boron	Leaves on the upper part of plant are yellow on top and reddish purple on the underside; internodes are short
Molybdenum	Generally yellow, stunted plants

Laboratory Analysis

Both soil and plant tissue test results are used to detect plant nutrient deficiencies. These two tests differ in their ability to reliably diagnose nutrition problems in alfalfa (Table 3). To fully understand and correct problems, test both soil and tissue.

Table 3. Relative reliability of soil and plant tissue testing for detecting secondary or micronutrient deficiency.

Nutrient	Soil Testing	Plant Tissue Testing
Sulfur	Very poor	Excellent
Boron	Poor	Excellent
Molybdenum	Not recommended	Excellent

Soil Testing

Soil tests provide an estimate of nutrient availability for uptake by plants and are most useful for assessing the fertility of fields prior to planting. Soil sampling methods are critical, since soil samples must adequately reflect the nutrient status of the field. Because a representative sample of an entire field gives an average of all the variation in that field, it is not the best way to develop recommendations for parts of the field that are less productive. The best technique is to divide each field into two or three areas representing good, medium, and poor alfalfa growth. Within each area establish permanent benchmark locations approximately 50 x 50 feet in size (See Figure 5.1 in *Intermountain Alfalfa Management*, UC Publication #3366). To ensure that you will be able to find each benchmark area again, describe it in relation to measured distances to specific landmarks on the edge of the field. By using this method to collect soil and plant tissue samples, you will be able to compare areas of the field with different production levels, develop appropriate management responses, and track changes over the years. The best time to sample soil is soon after an irrigation or rainfall, so the probe easily penetrates the moist soil. Before taking a soil sample, remove debris or residual plant material from the soil surface. The sample can be taken with a shovel, but an Oakfield tube or similar sampling probe is preferred. Sample the top 6 to 8 inches of soil. Take 15 to 20 cores at random from each benchmark area and mix them thoroughly in a plastic bucket to produce a single 1 pint composite sample for each benchmark area. A fewer number of cores (8-10) to make up samples from the second, third and fourth foot of soil is desirable to evaluate potential salt problems. Place each sample in a separate double-thick paper bag and dry the soil at room temperature before mailing to the laboratory. To get a complete profile of the nutrition status of an alfalfa field, perform all the soil and tissue tests cited in Table 4. A list of laboratories is found in University of California Special Publication 3024, *California Commercial Laboratories Providing Agricultural Testing*.

Table 4. Suggested tests for a complete examination of soil and alfalfa tissue for secondary and micronutrients.

Soil[1]	Plant tissue
PH	Sulfur (SO_4-S)
ECe	Boron
Calcium, magnesium, sodium	Molybdenum
SAR	Copper

[1] These tests evaluate factors that affect the availability of nutrients and the presence of undesirable salt levels. ECe (electrical conductivity of saturated paste extract (mmho/cm). SAR (sodium absorption ratio).

Taking soil samples every year may not be necessary once historical trends have been established. Sampling benchmark areas every time alfalfa is planted is usually sufficient to establish trends. If poor alfalfa growth is observed in other parts of the field, take samples from both good and poor growth areas so the fertility level or potential salt problem of the two areas can be compared. Since the only micronutrient for which a soil test is suggested is to evaluate possible toxicity of boron the values given are 0.1--0.2 for marginal, 0.2--0.4 for adequate, and >0.4 ppm for high levels. Soil test levels above 0.4 may be toxic for sensitive crops such as cereals. Soil test levels below 0.1 would suggest the use of plant tissue testing to diagnose deficiency. An economic yield response to fertilizer application is very likely for values below the deficient level, somewhat likely for values in the marginal level, and unlikely for values over the adequate level.

Plant Tissue Testing

By far the most precise method of determining the nutrient needs of alfalfa is plant tissue testing. Such tests are the best reflection of what the plant has taken up and are far more accurate than soil tests, particularly for sulfur, boron, and molybdenum. Plant tissue tests are useful in monitoring the nutrition status and evaluating the effectiveness of current fertilization practices. The best time to take a tissue sample is when the crop is in the 1/10 bloom growth stage or when regrowth measures 1/4 to 1/2 inch in length. (Alfalfa is often cut prior to 1/10 bloom to attain high-quality forage.) When alfalfa is cut prior to 1/10 bloom (for example, bud stage) nutrient concentrations should be approximately 5 per cent higher than when sampled at 1/10 bloom. Samples can be collected at any cutting, but collection at first cutting is preferred because it is the best time to detect a sulfur deficiency. Collect 40 to 60 stems from at least 30 plants in each of the benchmark areas. Different plant parts are analyzed for different nutrients (See Figure 5.2 in *Intermountain Alfalfa Management*, UC Publication #3366). Cut each sample into 3 sections of equal length. Discard the bottom third; place the top one third in one paper bag and the middle one third in another. Dry the samples in a warm room or oven. After drying, separate leaves from stems in middle one third sample by rubbing the sample between your hands. Put leaves and stems into separate bags. Table 4 lists the analyses that should be performed on the samples. Table 5 lists guidelines for interpreting plant tissue-test results. Entire plant samples or baled hay samples are not recommended because they can only detect extreme nutrient deficiencies.

Tissue tests can determine only the single most limiting nutrient affecting plant growth—the concentration of other nutrients may actually increase due to reduced growth. Therefore, correct the most severe deficiency first. After it is corrected, take new plant tissue samples to determine if other nutrients are deficient. Also, low concentrations of a nutrient in plant tissue may not always indicate a deficiency in the soil. Remember that plant analysis reflects nutrient uptake by the plant; a problem affecting roots, such as nematodes, can affect nutrient uptake as well.

Table 5. Interpretation of test results for alfalfa plant tissue samples taken at 1/10 bloom[1].

	Plant Tissue Value, ppm[2]			
Nutrient	Deficient	Marginal	Adequate	High
Sulfur (SO_4-S) Middle 1/3, leaves	0-400	400-800	800-1000	Over 1000
Boron Top third	Under 15	15-20	20-40	Over 200[3]
Molybdenum Top third	Under 0.3	0.3-1.0	1-5	5-10[4]

[1] Concentrations should be higher if alfalfa is cut at bud stage (multiply tabular value by 1.05).
[2] An economic yield response to fertilizer application is very likely for values below the deficient level, somewhat likely for values in the marginal level, and unlikely for values over the adequate level.
[3] A concentration over 200 may cause reduced growth and vigor.
[4] A concentration over 10 may cause molybdenosis in ruminant animals.

CORRECTION OF NUTRIENT DEFICIENCIES

Apply fertilizer to correct nutrient deficiencies after careful consideration of the amount of nutrients removed by alfalfa, the yield potential of the field, current soil-test levels, and historical responses to fertilization. Table 6 indicates the amount of nutrients removed by 4-, 6- and 8-ton alfalfa crops.

Table 6. Nutrients contained in 4, 6 and 8 tons of alfalfa hay[1].

		Nutrient Yield, lbs/A		
Nutrient	Symbol	4-ton crop	6-ton crop	8-ton crop
Nitrogen	N	240	360	480
Phosphorus	P_2O_5	48	72	96
Potassium	K_2O	200	300	400
Calcium	Ca	128	192	256
Magnesium	Mg	27	40	53
Sulfur	S	16	24	32
Iron	Fe	1.5	2.3	3.0
Manganese	Mn	1.0	1.5	2.0
Chlorine	Cl	1.0	1.5	2.0
Boron	B	0.2	0.4	0.5
Zinc	Zn	0.2	0.3	0.4
Copper	Cu	0.06	0.1	0.13
Molybdenum	Mo	0.008	0.012	0.016

Sulfur

Historically, sulfur has received considerable attention as being one of the more commonly deficient nutrients in alfalfa. Visual deficiency symptoms include stunting and light green or yellow color--symptoms that may also indicate nitrogen or molybdenum deficiency. Only tissue testing can confirm a sulfur deficiency; soil tests do not provide reliable results. It is important to have an adequate level of available sulfate sulfur in the soil at the time of planting. Two principle forms of sulfur exist: (1) long-term slowly available elemental sulfur and (2) short-term rapidly available sulfate. The most economical practice is to apply and incorporate before planting 200 to 300 pounds elemental sulfur per acre. Elemental sulfur is gradually converted to the sulfate form and should last 4 to 7 years. It may be necessary to repeat the application once in the life of a 6- to 10-year stand. To ensure a multiple-year supply of available sulfur, the particle size of elemental sulfur must range from large to small. Small particles are rapidly converted to the sulfate form; the large particles will continue to release sulfate over several years. Ideally, 10 percent of elemental sulfur should pass through a 100-mesh screen; 30 percent, through a 50-mesh screen; and the remaining 60 percent, through a 6-mesh screen. Very fine grades of sulfur are readily available but do not persist long enough to provide a multiple-year supply.

Fertilizers used to supply the sulfate form of sulfur include gypsum (15 to 17% sulfur), 16-20-0 (14 to 15% sulfur), and ammonium sulfate 21-0-0 (24% sulfur). Some growers apply 300 to 500 pounds gypsum per acre every other year rather than using elemental sulfur. The advantage to this practice is a quick response (about 2 weeks). The disadvantages are the higher cost per pound of sulfur and the fact that more sulfur is applied than necessary. Perhaps the most important reason to avoid overfertilization with sulfur is that it can decrease the selenium concentration in the alfalfa hay. Livestock producers throughout many of the sulfur deficient regions want forage that is as high in selenium as possible because their animals often suffer from selenium deficiency.

Iron

On rare occasion, growers have observed symptoms of iron deficiency in alfalfa, but only tissue tests have been partially effective in confirming the problem. Recent research has indicated that "active iron" with a minimum of 20-40 ppm concentration in plant tissue rather than "total iron" may be a more effective diagnostic tool. The deficiency produces nearly white or canary yellow plants in areas where drainage is poor. Iron deficiency in alfalfa is characteristically associated with high pH or poorly drained soils high in lime. If the soil pH is greater than 8.0 and free lime is present, begin to correct the iron deficiency by applying high rates of elemental sulfur (at least 1,000 pounds per acre); this will lower the soil pH. Also, improve drainage in low areas of the field.

Boron

Although deficiency symptoms are easily identified, boron deficiency is more effectively confirmed with a plant tissue test. Adequate supplies of boron are far more important for production of alfalfa seed than hay. When tissue tests indicate boron is deficient and boron-sensitive crops such as cereals are likely to be planted in the field within 12 months, apply 1 to 3 pounds boron per acre to the soil surface. Use 3.5 to 7 pounds per acre if boron-tolerant crops such as alfalfa, sugarbeets, or onions will be grown for the next 24 months. Use the lower rates on sandy soils; the higher rates are suggested for fine-textured soils. Higher rates of boron will often last 5 to 7 years. The most common boron fertilizers are 45 to 48 percent borate (14.3 to 14.9% boron) and 65 to 68 percent borate (20.4 to 21.1% boron). Boron is usually applied as a granular product, either by air or through the small seed box in a grain drill. Some forms can be applied as a liquid along with herbicide applications; make sure the boron and herbicide are compatible before mixing them.

Molybdenum

Molybdenum deficiency is somewhat likely to occur in the Sacramento Valley, the Intermountain region of Northern California and further north in Oregon and Washington. Symptoms of molybdenum deficiency are like those of nitrogen and sulfur deficiency: light green or yellow stunted plants. A positive response to ammonium sulfate fertilizer could mean a nitrogen, sulfur, or molybdenum deficiency. A positive response to urea rules out a sulfur deficiency but could indicate a shortage of nitrogen or molybdenum. Plant tissue testing or applying sulfur and molybdenum fertilizers to separate trial strips are the only means of confirming a molybdenum deficiency. The most common molybdenum fertilizer is sodium molybdate (40% molybdenum), but ammonium molybdate can be used as well. Apply 0.4 pound molybdenum per acre during the winter or before regrowth has occurred after cutting. A single application of molybdenum should last from 5 to 15 years. Thorough records of molybdenum application times and amounts along with repeated tissue testing are essential to determine when to apply or reapply the nutrient. Do not apply excessive molybdenum (that is, double or triple coverage with the sprayer)—the concentration of the element in alfalfa may become so high that the forage becomes toxic to livestock. For the same reason, do not apply molybdenum to foliage. Analyzing the top third of the plant for both copper and molybdenum can detect deficiencies and suboptimum ratios of these elements. Consult a nutrition specialist if you suspect molybdenum problems.

RECORD KEEPING

Clear and complete records are essential to a successful alfalfa fertility program. Keep a record for each field and include the location of permanent benchmark areas, dates of sampling, soil and plant tissue test results, fertilizer application dates, fertilizers applied and the rate of application, and crop yields. This information can help you evaluate both the need for and the response to applied fertilizer and allow you to develop an economical, long-term fertilization program.

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