Buy Manual

Alfalfa Fertilization Strategies

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UNIVERSITY OF CALIFORNIA
Division of Agriculture and Natural Resources
Publication 8292
12/2007
http://anrcatalog.ucdavis.edu

Chapter 6

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UC PEER REVIEWED

This publication is **Chapter 6** of a 24-chapter series on Irrigated Alfalfa Management published by the University of California Alfalfa & Forage Systems Workgroup. Citation: Meyer, R. D.; Marcum, D. B.; Orloff, S. B.; Schmierer, J. L. 2007. Alfalfa fertilization strategies. IN C. G. Summers and D. H. Putnam, eds., Irrigated alfalfa management for Mediterranean and Desert zones. Chapter 6. Oakland: University of California Agriculture and Natural Resources Publication 8292. See: http://alfalfa.ucdavis.edu/IrrigatedAlfalfa

Providing an adequate supply of nutrients is important for alfalfa production and is essential for maintaining high and profitable yields. However, supplying proper plant nutrition requires complex and often difficult management decisions. The process includes an analysis of which nutrients are needed, selection of the proper fertilizer, application rate, timing and placement, economics, record keeping, and environmental considerations. This chapter serves as a guide to alfalfa fertilization in the arid and semi-arid alfalfa production regions of the world, which include the Sacramento, San Joaquin, and Imperial Valleys of California, and coastal valley regions of the state. Information on appropriate methods of sampling alfalfa and interpreting soil and tissue tests are included.

Before applying fertilizer to alfalfa, consider other factors that may limit yield. It makes little sense to apply fertilizers when another factor is more limiting to plant growth. For example, an application of phosphorus, even when phosphorus is deficient, may not increase yields if water is not sufficient to allow plants to grow in response to the 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 yield and fertilizer application history; and, most importantly, the location of the samples. The advent of GPS (global positioning system) technology provides for accurate location of where samples are taken, allowing the sampler to return to the same location for future sampling.

TABLE 6.1

Common nutritional and fertilizer requirements of alfalfa in arid and semi-arid regions

Element Needed	Symbol	Fertilizer Required[a]
Nitrogen	N	Seldom
Phosphorus	P	Frequently
Potassium	K	Less frequently
Calcium[b]	Ca	Never
Magnesium	Mg	Less frequently
Sulfur[c]	S	Less frequently
Iron	Fe	Never
Manganese	Mn	Never
Chlorine	Cl	Never
Boron	B	Seldom
Zinc	Zn	Never
Copper	Cu	Never
Molybdenum[d]	Mo	Less frequently
Nickel	Ni	Never
Cobalt[e]	Co	Never

a. Frequently: 25% or more of the acreage shows need for fertilization with this nutrient. Less frequently: Less than 25% of the acreage shows need for fertilization.
Seldom: Less than 1% of the acreage shows need for fertilization.
Never: A deficiency has never been reported or observed.
b. Liming materials containing calcium are used for pH amendment of acid soils.
c. Various forms of sulfur are used for soil salinity management.
d. Needed in Sacramento Valley but may be in excess in San Joaquin and Imperial Valleys and coastal valleys.
e. Necessary for nitrogen fixation only.

Essential Plant Nutrients

Seventeen elements are needed, in varying amounts, for plant growth (see Table 6.1). 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 the essential elements. Thus, all nutrients must be available to the plant in adequate quantities throughout the production season. The nutrients that are most commonly in short supply for alfalfa production are phosphorus, followed by potassium, sulfur, molybdenum, and boron (Table 6.1).

Diagnosis of Nutrient Deficiencies

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

Visual Observation

Nutrient deficiencies may be expressed as visual plant symptoms, such as obvious plant stunting or yellowing. Table 6.2 summarizes visual symptoms of common deficiencies (also see Color Plates 6.1 through 6.7 at the end of this chapter). Unfortunately, visual symptoms are seldom definitive and can be easily confused or mistaken for symptoms caused by other factors, such as insect injury, diseases, excess water, salt or water stress, restricted root growth, or rodent damage. Additionally, significant yield losses may have already occurred by the time the symptoms appear. Thus, visual diagnosis should always be confirmed with laboratory analysis or test strips with selected fertilizers.

Soil and Tissue Testing

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 6.3). To fully understand and correct problems, test both soil and tissue.

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 a field. Although a single representative sample of an entire field provides an average value, 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 areas. Studying soil maps of a field may be helpful, but delineating these production areas based on variations in plant growth is more effective. Within each area, establish permanent benchmark locations measuring approximately 50 × 50 feet (15 × 15 m) (Fig. 6.1). 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 or with the help of global positioning systems. By using this method to collect soil and plant tissue samples, a grower 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 irrigation or rainfall, when the probe can easily penetrate 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 a hollow, open-faced

TABLE 6.2

Nutrient deficiency symptoms observed in alfalfa

Deficiency	Symptoms
Nitrogen	Generally yellow, stunted plants
Phosphorus	Stunted plants with small leaves; sometimes leaves are dark blue-green
Potassium	Pinhead-size yellow or white spots on margins of upper leaves; on more mature leaves, yellow turning to brown leaf tips and edges
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

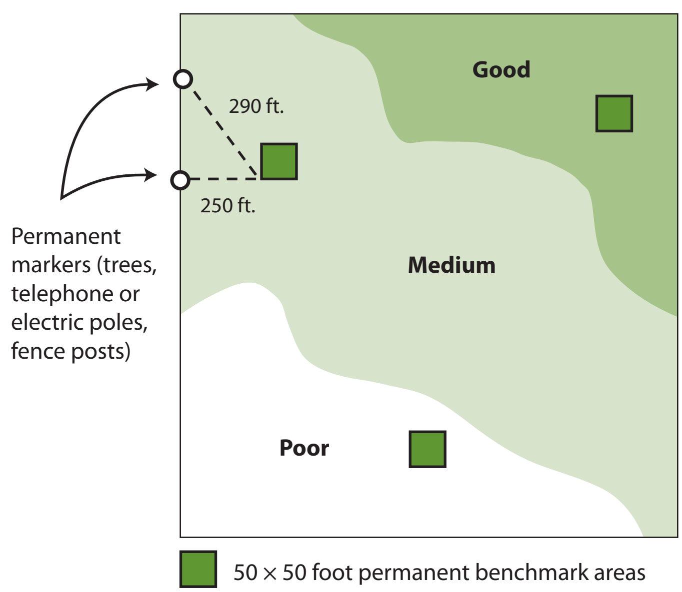
TABLE 6.3

Relative reliability of soil and plant tissue testing for nutrient deficiency

Nutrient	Soil Testing	Tissue Testing
Phosphorus	Good	Excellent
Potassium	Good	Excellent
Sulfur	Very poor	Excellent
Boron	Poor	Excellent
Molybdenum	Not recommended	Excellent

FIGURE 6.1

Recommended soil and plant tissue sampling procedures involve establishing permanent benchmark sampling locations (50 × 50 feet or 5 × 5 m) within areas of the field that support good, medium, and poor alfalfa growth. Define these benchmark areas in relation to measured distances to specific landmarks on the edge of the field or use global positioning systems.



tube, such as an Oakfield soil probe, is preferred. Sample the top 6–8 inches (15–20 cm) of soil unless a salt problem or an acidic soil is suspected. If this is likely, then the second foot (12–24 inches [30–60 cm]) and even the third foot (24–36 inches [60–90 cm]) should also be sampled. 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 (0.47 L) composite sample for each benchmark area. Since there is usually less variability, only 8 to 12 cores need to be composited for the second- and third-foot samples. Place each sample in a separate double-thick paper bag and air dry the soil at room temperature before mailing to the laboratory. To get a complete assessment of the nutrition status of an alfalfa field, perform all the soil and tissue tests cited in Table 6.4. A list of laboratories is found in University of California Special Publication 3024, *California Commercial Laboratories Providing Agricultural Testing.*

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 of the two areas can be compared. Table 6.5 lists guidelines for interpreting soil test results with values given for deficient, marginal, adequate, and high levels. 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 (Table 6.5).

Plant tissue testing...by far the most precise method of determining the nutrient needs of alfalfa.

TABLE 6.4

Suggested tests for a complete examination of soil and alfalfa tissue

Soil	Plant Tissue
pH[a]	Phosphorus (PO_4–P)
Phosphorus	Potassium
Potassium	Sulfur (SO_4–S)
EC_e[a]	Boron
Calcium, Magnesium, Sodium[a]	Molybdenum
SAR[a]	Copper

a. These tests evaluate factors that affect the availability of nutrients and the presence of undesirable salt levels. EC_e = electrical conductivity of saturated paste extract (dS/m or mmho/cm); SAR = sodium adsorption ratio.

Plant Tissue Testing

The most precise method of determining the nutrient needs of alfalfa is plant tissue testing. Although soil tests are helpful, plant tissue 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 nutritional status and evaluating the effectiveness of current fertilization practices.

The best time to take a tissue sample is when the crop is at the one-tenth bloom growth stage or when regrowth length measures ¼–½ inch (0.6–1.3 cm). Since alfalfa is often cut before one-tenth bloom (e.g., bud stage) to attain high-quality forage, preliminary

TABLE 6.5

Interpretation of soil test results for alfalfa production

Nutrient	Extract[b]	Soil Value (ppm)[a]			
		Deficient	Marginal	Adequate	High
Phosphorus	Bicarbonate	<5	5–10	10–20	>20
Potassium	Ammonium acetate	<40	40–80	80–125	>125
Boron	Saturated paste	0.1[c]	0.1–0.2	0.2–0.4	>0.4[d]

a. An economic yield response to fertilizer application is very likely for values below the deficient level, somewhat likely for values in the marginal range, and unlikely for values over the adequate level.

b. Soil test values are based on use of the cited extract; values for other extracts are different.

c. Soil testing is not a suitable method to diagnose a deficiency. Use a plant tissue test.

d. Possible toxicity to sensitive crops, such as cereals.

research results indicate that phosphorus concentration should be 1,200 ppm PO_4–P at mid-bud and even higher, 1,600 ppm, at very early bud stage. Other nutrient concentrations should be approximately 10 percent higher than when sampled at the one-tenth bloom growth stage. 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 same benchmark areas from which the soil samples are collected.

Different plant parts are analyzed for different nutrients (Fig. 6.2). Cut each sample into three sections of equal length. Discard the bottom one-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 the middle one-third sample by rubbing the sample between your hands. Put leaves and stems into separate bags. Figure 6.2 and Table 6.6 list the analyses that should be performed on the samples. Table 6.6 gives guidelines for interpreting plant tissue-test results. The top 6 inches (15 cm) or one-third of the plant, or even whole plant samples collected from baled hay, can give an approximate concentration of phosphorus, potassium, sulfur, molybdenum, or boron for nutrient evaluation. Table A in the Appendix (at the end of this chapter) is useful for interpreting these analytical results.

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.

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 and plant tissue-test levels, and historic responses to fertilization. Table 6.7 indicates the amounts of nutrients removed by 6-, 8-, 10-, and 12-ton per acre (13.4-, 17.9-, 22.4-, and 26.9-Mg/ha) alfalfa crops.

FIGURE 6.2

Plant tissue sampling and testing: (A) Collect 40 to 60 stems, including leaves from at least 30 plants. (B) Cut stems into three sections of equal length. (C) Discard the bottom third. Place the top third in one paper bag and the middle third in another. Dry the samples. Separate leaves from stems in middle third by rubbing between hands. Put leaves in one bag and stems in another bag. Analyze top-third sample for boron, molybdenum, and copper. Analyze leaves from the middle third for sulfur (SO_4–S) and the stems from middle third for phosphorus (PO_4–P) and potassium. See Table 6.6 for interpretation of data.

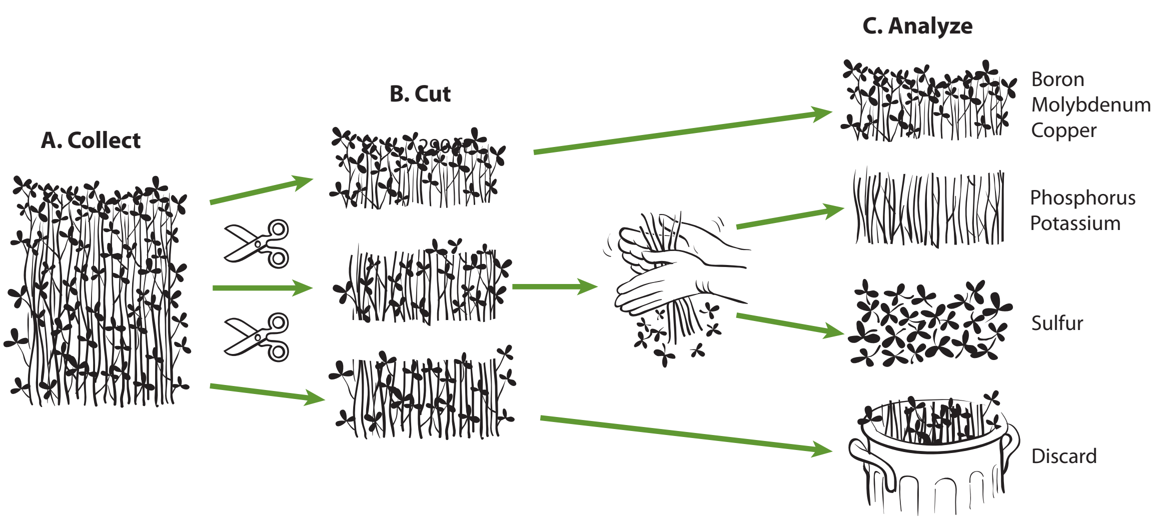


TABLE 6.6

Interpretation of test results for alfalfa plant tissue samples taken at one-tenth bloom

Nutrient	Plant Part	Unit	Plant Tissue Value[a]			
			Deficient[b]	Marginal	Adequate	High
Phosphorus (PO_4–P)	Middle third, stems	ppm	300–500	500–800	800–1,500	Over 1,500
Potassium	Middle third, stems	%	0.40–0.65	0.65–0.80	0.80–1.5	Over 1.5[c]
Sulfur (SO_4–S)	Middle third, leaves	ppm	0–400	400–800	800–1,000	Over 1,000[d]
Boron	Top third	ppm	Under 15	15–20	20–40	Over 200[e]
Molybdenum	Top third	ppm	Under 0.3	0.3–1.0	1–5	5–10[f]

a. Phosphorus concentration should be higher if alfalfa is cut at bud stage, 1,200 ppm at mid-bud, and even higher, 1,600 ppm, if cut at very early bud stage. Other nutrient concentrations should be approximately 10% higher than when sampled at the one-tenth bloom growth stage (multiply tabular values by 1.10), (ppm = mg/kg).

b. An economic yield response to fertilizer applications 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.

c. Alfalfa having greater than 3% potassium may cause animal health problems, particularly if the magnesium concentration is not greater than 0.25%.

d. Alfalfa having greater than 3,000 ppm SO_4–S may intensify molybdenosis in ruminants.

e. A concentration over 200 may cause reduced growth and vigor.

f. A concentration over 10 may cause molybdenosis in ruminants. Copper concentrations should be twice as high as molybdenum concentrations.

TABLE 6.7

Nutrients removed in 6, 8, 10, and 12 tons/acre of alfalfa hay

Nutrient	Symbol	Alfalfa Crop Yield[a]			
		6 ton/acre	8 ton/acre	10 ton/acre	12 ton/acre
		Nutrient Removal, lb/acre			
Nitrogen	N	360	480	600	720
Phosphorus	P (P_2O_5)	31 (71)	42 (95)	52 (119)	62 (143)
Potassium	K (K_2O)	240 (288)	320 (384)	400 (480)	480 (576)
Calcium	Ca	192	256	320	384
Magnesium	Mg	40	53	66	79
Sulfur	S	24	32	40	48
Iron	Fe	2.3	3.0	3.8	4.6
Manganese	Mn	1.5	2.0	2.5	3.0
Chlorine	Cl	1.5	2.0	2.5	3.0
Boron	B	0.4	0.5	0.6	0.7
Zinc	Zn	0.3	0.4	0.5	0.6
Copper	Cu	0.12	0.16	0.20	0.24
Molybdenum	Mo	0.024	0.032	0.04	0.048

a. Nutrient quantities are given on a 100% dry matter basis, (ton/acre × 2.24 = Mg/ha, and lb/acre × 1.12 = kg/ha).

Nitrogen

Applying nitrogen fertilizer to alfalfa is seldom beneficial or profitable. Adequate nitrogen is almost always provided by the symbiotic nitrogen-fixing bacteria (*Rhizobium meliloti* Dang.) that live in nodules on alfalfa roots (Fig. 6.3). *Symbiotic* means that both the plants and bacteria benefit. The alfalfa plants benefit from the nitrogen provided by rhizobia, and the bacteria benefit from the food source (carbohydrates) provided by the alfalfa plants. Because of this relationship, applying nitrogen to alfalfa seldom results in an economic yield response. In those rare cases where nitrogen fertilizer does result in a yield increase, the problem is probably ineffective inoculation or conditions that inhibit or retard the development of the rhizobia (e.g., low soil pH, waterlogged soils, cold conditions, compacted soil, or extremely shallow root zone). Molybdenum and cobalt deficiencies are other possibilities.

Symptoms of nitrogen deficiency include stunted growth and a light green or yellow color. A nitrogen deficiency is suspected when the newly planted field contains stunted or small, yellow plants along with scattered tall, dark-green, inoculated plants (Color Plates 6.2 and 6.3). An examination of the roots usually shows no nodules on the stunted, yellow plants and several nodules on the green, healthy plants. Poor nodulation is often associated with fields having no history of alfalfa production; a low soil pH (<6.3); use of outdated inoculant; or hot, dry seedbed conditions.

FIGURE 6.3

Nitrogen-fixing nodules are pinkish and easily dislodge from the root.

The most common cause of nitrogen deficiency is poor inoculation and nodule formation after planting. Proper inoculation is necessary to ensure that alfalfa has an adequate supply of nitrogen. Most alfalfa seed currently purchased has been inoculated; however, if the field being seeded has not had a recent history of alfalfa, it would be desirable to inoculate the seed. For effective nodulation, inoculate seed with fresh inoculant, and do not expose it to hot, dry conditions prior to germination. Inoculants should be kept in cool areas and are preferably refrigerated before use. Inoculation is particularly critical in fields planted to a first crop of alfalfa. Fields with a history of alfalfa plantings seldom have inoculation problems as a result of high residual *Rhizobium* populations from previous crops. Planting preinoculated seed in these situations should be adequate to establish good inoculation.

*Applying nitrogen fertilizer to alfalfa is seldom beneficial or profitable. Adequate nitrogen is provided by the symbiotic nitrogen-fixing bacteria (*Rhizobium meliloti *Dang.) that live in nodules on alfalfa roots.*

If poor nodulation occurs in a young stand of alfalfa, inoculate seed at two to five times the normal rate, and drill it into the stand at 3–5 pounds seed per acre (3.4–5.6 kg/ha). Follow with a light irrigation. If it is discovered after the alfalfa has been planted that the soil pH is below 6.3, then surface-applied lime at approximately 1 ton per acre (2.24 Mg/ha) may establish inoculation of the alfalfa. Also, it is desirable to apply 40–50 pounds nitrogen per acre (45–56 kg/ha) per cutting to retain stand density until the plants become inoculated. Usually, after the alfalfa has overwintered, all plants in the field will be inoculated.

Light green or yellow plants may also indicate a sulfur or molybdenum deficiency. Use a plant tissue test to identify the specific deficiency. Nitrogen deficiency may also result from a molybdenum deficiency, since molybdenum has a role in nitrogen fixation. Sulfur and molybdenum deficiencies will be discussed later in this chapter.

Phosphorus

Phosphorus is the most commonly deficient nutrient in alfalfa in the Sacramento, San Joaquin, and Imperial Valleys, in coastal California valleys, and in many other alfalfa producing environments in Mediterranean and desert zones. Before planting, use a soil test to assess the phosphorus and potassium needs, as soil tests are fairly reliable for determining the status of these nutrients in the soil (this is not the case for sulfur, boron, or molybdenum). As indicated in Table 6.5, soil with a phosphorus level of less than 5 parts per million (ppm or mg/kg) is considered deficient; soil with 5–10 ppm phosphorus is marginal; and soil with 10 ppm or greater phosphorus is initially adequate. A plant tissue test for phosphorus is preferred over soil testing after alfalfa is established. Phosphorus deficiency is very difficult to identify visually (Color Plate 6.1) because it looks like moisture stress or several other stresses that cause stunted plants with dark leaves.

To correct a phosphorus deficiency, a high-analysis phosphorus fertilizer, such as 0-45-0, 11-52-0, or liquid 10-34-0, is usually the most economical. In alfalfa, these three common phosphorus sources result in the same yield response per pound of P_2O_5 applied. Liquid or granular phosphorus fertilizers with water solubility values greater that 55 percent are nearly equal in terms of plant availability. Rock phosphate, however, is not recommended because of low phosphate availability, particularly when applied to anything other than very acid soils (those with a pH less than 5.5). When higher nitrogen-containing fertilizers, such as 16-20-0 or 18-46-0, are applied prior to or at planting, take care to control weeds because the supplemental nitrogen will stimulate their growth.

Before planting, use soil tests to determine the amount of phosphorus needed (Table 6.8). Incorporate no more than a 2-year supply of fertilizer into the top 2–4 inches (5–10 cm) of soil. Use a double disk to incorporate and mix the fertilizer with the soil. Avoid deep plowing after spreading the fertilizer because this decreases the efficient uptake of phosphorus by the plant. Even if high rates of phosphorus are applied (>200 lb P_2O_5 per acre, [224 kg/ha]), it may be economical to reapply after 2 years. Use plant tissue analysis to determine the need for phosphorus after the seedling year. Applying phosphorus fertilizers on the soil surface in an established stand has been very effective. Apply fertilizer any time, but applications made from October through February are preferred because alfalfa responses to phosphorus fertilizer are not usually observed until 60 to 90 days after application.

Table 6.8 gives a range of application rates because some soils and growing conditions require larger amounts to meet nutritional requirements and maintain high alfalfa yields. Various combinations of phosphorus amounts and application timing can be used to achieve the rates recommended. Recent UC Davis

TABLE 6.8

Recommended phosphorus and potassium application rates based on results of soil or plant tissue tests

Nutrient	Yield Level (ton/acre)	Soil or Plant Tissue Test Result: Deficient[a]	Marginal	Adequate
		Application Rate, lb/acre		
Phosphorus (P_2O_5)	8	120–180	60–90	0–45
	12	180–270	90–130	0–60
Potassium (K_2O)	8	300–400	150–200	0–100
	12	400–600	200–300	0–150

a. An economic yield response to fertilizer applications 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 (ton/acre × 2.24 = Mg/ha; lb/acre × 1.12 = kg/ha).

research has indicated that fewer applications (at least every 2 years) of higher rates can be applied more economically than lower rates (less than 50 lb P_2O_5 per acre [56 kg/ha]) applied each year. For more efficient use of phosphorus fertilizers, single application rates should not exceed 100–150 pounds P_2O_5 per acre (112–168 kg/ha) and should be applied during late fall or winter prior to alfalfa growth. If higher rates of phosphorus are needed, then apply half in late fall or winter prior to alfalfa growth and the second half after the second or third cutting. Mid-season applications of phosphorus can be injected into the irrigation water provided there is good water distribution and no tailwater leaves the ranch. It can also be applied on the soil surface as either dry granular or a liquid fertilizer before the initiation of much regrowth. Take plant tissue samples 60–90 days after a fertilizer application to re-evaluate the fertility status.

Potassium

Potassium deficiency is less frequent in the Imperial Valley and coastal valleys of California but is often observed on the east side of the Sacramento and northern San Joaquin Valleys, where soils tend to be low in potassium. Like a lack of phosphorus, a potassium deficiency can be diagnosed by either a soil or plant tissue test. The visual symptoms of potassium deficiency are pinhead-size white or yellow spots on new leaves (see Color Plate 6.6). Unlike the symptoms of other nutrient shortages, those of potassium deficiency are distinctive and fairly reliable. Note, however, that genetic differences between alfalfa plants affect symptom development; not all potassium-deficient plants show deficiency symptoms.

The visual symptoms of potassium deficiency are pinhead-size white or yellow spots on new leaves. Unlike the symptoms of other nutrient shortages, those of potassium deficiency are distinctive and fairly reliable.

Also, some insects, such as blue alfalfa aphid, and diseases cause symptoms similar to those of potassium deficiency.

The most economical fertilizer for correcting this deficiency is muriate of potash (0-0-60). Sometimes potassium sulfate (0-0-52, 18% sulfur) is used when sulfur is also deficient. However, compared to muriate of potash, potassium sulfate and other mixed fertilizers are usually more expensive per pound of potassium. Table 6.8 lists recommended potassium rates for both preplant-incorporated and surface applications. Applications on the soil surface are very effective and can be made at any time. For the most efficient use of the potassium fertilizers, single application rates should not exceed 200–300 pounds K_2O per acre (224–336 kg/ha) and should be applied during late fall or winter prior to alfalfa growth, and again if needed after the second or third cutting. Like phosphorus, the growth response to applied potassium may not be observed until 60–90 days after fertilizer application.

Sulfur

Historically, sulfur has only been deficient in alfalfa in the Sacramento Valley and perhaps the east side of the northern San Joaquin Valley. Visual deficiency symptoms include stunting and a light green or yellow color—symptoms that may also indicate nitrogen or molybdenum deficiency (see Color Plates 6.2 and 6.4). 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 fertilizer 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 200–300 pounds of elemental sulfur per acre (224–336 kg/ha) before planting. Elemental sulfur is gradually converted to the sulfate form and should last 3 to 5 years or longer.

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 (15–17% sulfur), ammonium sulfate 21-0-0 (24% sulfur), and 16-20-0 (14–15% sulfur).

Gypsum, as well as elemental sulfur and other materials, are often used to aid in water penetration of "low-salt" content irrigation water and reclamation of "high-salt" content soils. Growers may apply from 500 to 1,000 pounds of gypsum per acre (560–1,120 kg/ha) every year or two to accomplish these objectives.

Iron

On rare occasions, growers have observed symptoms of iron deficiency in alfalfa, but only tissue tests have been helpful in confirming the problem. The deficiency produces nearly white or canary-yellow plants in areas where drainage is poor. Iron deficiency in alfalfa is 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 lowering the soil pH using high rates of elemental sulfur (at least 1,000 lb per acre [1,120 kg/ha]). Also, it is important to improve drainage in low areas of the field.

Boron

Although deficiency symptoms are easily identified (Color Plate 6.7), boron deficiency is more effectively confirmed with a plant tissue test. Early stages of boron deficiency are often associated with drought conditions and, in a few cases, potassium deficiencies. Adequate supplies of boron are more important for production of alfalfa seed than for production of alfalfa 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, broadcast 1–3 pounds of boron per acre (1.12–3.36 kg/ha) on the soil surface. Use higher rates of 3.5–7 pounds per acre (3.9–7.8 kg/ha) 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 provide an adequate supply for 5–7 years. The most common boron fertilizers are 45–48 percent borate (14.3–14.9% boron) and 65–68 percent borate (20.4–21.1% 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.

Adequate supplies of boron are more important for production of alfalfa seed than for production of alfalfa hay.

Molybdenum

Molybdenum deficiency is infrequent in the Central Valley, but has been found on the west side of the Sacramento Valley. Generally toxicities of molybdenum are more likely to occur in the San Joaquin and Imperial Valleys and some of the coastal valleys. Symptoms of molybdenum deficiency are like those of nitrogen and sulfur deficiency: light green or yellow, stunted plants (Color Plates 6.2 and 6.5). 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 per acre of molybdenum (1 pound per acre or 1.12 kg/ha sodium molybdate) during winter or before regrowth has resumed after cutting. Broadcast on the soil surface only and avoid application to any plant foliage. A single application of 0.4 pound per acre 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)—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 directly on foliage. Analyzing the top one-third of the plant for both copper and molybdenum can detect deficiencies and suboptimum ratios of these elements. Consult an animal nutrition specialist if you suspect molybdenum problems.

Record Keeping

Clear and complete records are essential to a successful alfalfa fertilization program. Keep a record for each field and include the location of permanent benchmark sampling 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.

Additional Reading

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Appendix

TABLE A

Interpretation of test results for alfalfa plant tissue samples taken at one-tenth bloom for top 6 inches or one-third of plant samples or whole plant samples collected from baled hay

		Plant Tissue Value[a]			
Nutrient	**Unit**	**Deficient[b]**	**Marginal**	**Adequate**	**High**
Top 6 inches or one-third of plant sample					
Phosphorus	%	<0.20	0.21–0.25	0.26–0.70	>0.70
Potassium	%	<1.75	1.76–2.00	2.01–3.50	>3.5[c]
Sulfur	%	<0.20	0.20–0.25	0.26–0.50	>0.50[d]
Boron	ppm	<15	16–20	21–40	>200[e]
Molybdenum	ppm	<0.3	0.4–1.0	1–5	5–10[f]
Whole plant samples collected from baled hay					
Phosphorus	%	<0.20	0.21–0.22	0.23–0.30	>0.30
Potassium	%	<0.80	0.81–1.09	1.10–1.40	1.40–3.00[c]
Sulfur	%	<0.20	0.20–0.22	0.23–0.30	>0.40[d]
Boron	ppm	<15	16–20	21–80	>200[e]
Molybdenum	ppm	<0.3	0.4–1.0	1–5	5–10[f]

a. Phosphorus concentration should be higher if alfalfa is cut at bud stage, 0.26% at mid-bud and even higher, 0.28%, if cut at very early bud stage. Other nutrient concentrations should be approximately 10% higher than when sampled at the one-tenth bloom growth stage (multiply tabular values by 1.10), (ppm = mg/kg).

b. An economic yield response to fertilizer applications 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.

c. Alfalfa having greater than 3% potassium may cause animal health problems, particularly if the magnesium concentration is not greater than 0.25%.

d. Alfalfa having greater than 3,000 ppm SO_4–S, or approximately 0.4% sulfur, may intensify molybdenosis in ruminants.

e. A concentration over 200 may cause reduced growth and vigor.

f. A concentration over 10 may cause molybdenosis in ruminants. Copper concentrations should be twice as high as molybdenum concentrations.

Color Plates

PLATE 6.1

Phosphorus deficiency, although characterized by stunted plants with small leaves, is difficult—if not impossible—to identify visually, because many other problems cause similar symptoms. Contrast the phosphorus-deficient plants (left) with those that received phosphorus fertilizer (right).

PLATES 6.2

Nitrogen, sulfur, and molybdenum deficiencies all cause yellowing and stunting. (A,B,C) These photos illustrate the progressive development of the deficiency and chlorotic leaf symptoms (left) versus healthy leaves (right).

PLATE 6.3

Nitrogen deficiency is evident soon after planting, when seedlings reach 4 to 8 inches (10 to 20 cm) in height, In a field with nitrogen-deficient alfalfa, stunted yellow plants are scattered among taller dark green plants. The yellow plants result from poor inoculation by Rhizobia bacteria; the dark green plants have been adequately inoculated.


6.3

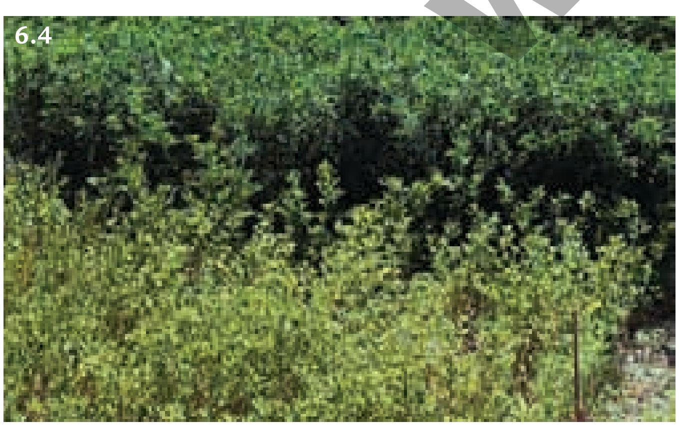
6.4

PLATE 6.4

Sulfur deficiency can occur at any time or growth stage, but it is most common in spring, when alfalfa starts growing and soils are cold or wet. Contrast the yellow sulfur-deficient plants with the green normal growth where sulfur was applied.


6.1


6.2a


6.2b


6.2c


6.5

PLATE 6.5

Molybdenum deficiency generally occurs after the first or perhaps second cutting. Regrowth of molybdenum-deficient alfalfa , like that of alfalfa deficient in sulfur, may be extremely yellow and stunted. This photo shows a strip of yellow plants between green plants; the green plants received an application of molybdenum.

PLATES 6.6

(A) The upper portion of this alfalfa stem exhibits potassium-deficiency symptoms. (B) The first symptoms to appear are yellow or white spots, each about the size of a pinhead, near the margins of upper leaves. (C and D) As the plant becomes more deficient, leaf tips and margins become more chlorotic. When leaves mature, the yellow tissue dies and turns brown.


6.6a


6.6b


6.6c


6.6d


6.7a

PLATES 6.7

(A) The yellow and reddish chlorotic leaf tips and margins associated with boron deficiency are somewhat similar to potassium-deficiency symptoms. (B) Leaves of boron-deficient alfalfa are reddish purple on the underside, and sometimes on the top. (C) After an irrigation, or when regrowth occurs, a new stem may initiate at the base of the third or fourth leaf from the top of the plant. The new stem appears normal at first, but the internodes (stem segments between leaves) become increasingly shorter. Later, the leaves of the new stem also exhibit boron-deficiency symptoms—yellow on top and reddish purple on the underside.


6.7b


6.7c

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Publication 8292
ISBN-13: 978-1-60107-536-9

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This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by the ANR Associate Editor for Pest Management.

12/07-WFS