Nutrient Management Guide for Dryland and Irrigated Alfalfa in the Inland Northwest

A PACIFIC NORTHWEST EXTENSION PUBLICATION • PNW0611

Washington State University • Oregon State University • University of Idaho

Nutrient Management Guide for Dryland and Irrigated Alfalfa in the Inland Northwest

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Nutrient management is necessary to produce high-yielding, high-quality alfalfa economically, while at the same time preserving soil, air, and water quality. As the term implies, nutrient management includes activities such as sampling to monitor soil and plant tissue nutrient levels, adjusting nutrient application rates based on soil and tissue test results, and varying the placement, timing, and source of nutrients to optimize plant availability and uptake.

The information presented here is applicable to alfalfa grown throughout Idaho and east of the Cascade mountain range in Oregon and Washington. Different climates, soils, and topography result in considerable variation in alfalfa yields across a region, an individual farm, and even within a field on the same farm. Due to this inherent variability, a one-size-fits-all recommendation for the management of any one nutrient is of little value. Nutrient management choices should be based on individual grower practices, realistic yield expectations, and current soil and tissue test information.

This document summarizes locally-based guidelines for managing major nutrients in alfalfa, emphasizes how producers can tailor recommendations to their production system, and identifies opportunities where information such as soil and tissue test results can help refine and improve nutrient management practices to optimize alfalfa yield, quality, and economic returns. The recommendations are based on existing Extension bulletins, recent research data, field experiences, and estimates of nutrient removal and efficiency.

Nutrient removal by alfalfa

Growing alfalfa removes large quantities of nutrients from soil (Table 1). In fact, high-yielding stands of alfalfa hay remove as much or more nutrients than any other intensive forage managed for hay or silage. Growers have historically relied on phosphorus and potassium as the main nutrients added for optimal alfalfa production. Areas with a long history of alfalfa and other intensive crops have commonly mined soil nutrient reserves. This, coupled with modern, higher-yielding varieties and production systems, means that many alfalfa fields now require supplementation with multiple nutrients.

Soil pH and alfalfa

Optimum alfalfa yields occur when soil pH is near 7.0; however, alfalfa can tolerate soil in the pH range 6.0–8.2 and still produce high yields. Northern Idaho and western Oregon and Washington, where rainfall is high, have lower soil pH than more arid regions of the inland

Table 1. Average tissue nutrient contents and their removal in alfalfa hay production.

Nutrient	Nutrient concentration in early bloom hay (dry matter basis)[1]	Nutrients removed per ton of early bloom alfalfa hay (analysis from previous column, 88% dry matter)	Range of nutrients removed per ton of hay at 88% dry matter[2]
Nitrogen (N)	19.9% crude protein (3% N)	56 lb N	50–70 lb N
Phosphorus (P)	0.2% P	8 lb P_2O_5[3]	8–16 lb P_2O_5
Potassium (K)	2.6% K	54 lb K_2O[4]	48–72 lb K_2O
Sulfur (S)	0.3% S	5 lb S	4–6 lb S
Calcium (Ca)	1.6% Ca	30 lb Ca	28–35 lb Ca
Magnesium (Mg)	0.3% Mg	6 lb Mg	5–8 lb Mg
Boron (B)	—	—	0.05 lb B
Zinc (Zn)	30 ppm[5] Zn	0.05 lb Zn	0.05 lb Zn
Copper (Cu)	12.7 ppm[5] Cu	0.02 lb Cu	0.02 lb Cu
Molybdenum (Mo)	0.29 ppm[5] Mo	0.0005 lb Mo	0.0005 lb Mo

[1]Adapted from National Research Council 2000, pp. 134–135.
[2]Variations in nutrient removal that may occur with different soil residual nutrient values.
[3]To convert P (phosphorus) to P_2O_5 (oxide form), divide by 0.44.
[4]To convert K (potassium) to K2O (oxide form), divide by 0.83.
[5]parts per million

Figure 1. Symptoms of phosphorus deficiency in alfalfa include short plants, thin and weedy stands, and small, dark, or blue-green leaves. The overview photo is of a severely phosphorus-deficient stand of alfalfa. The left insert photo is of a phosphorus-deficient stand, while the right insert photo is of a phosphorus-fertilized stand.

Pacific Northwest. Soil pH below 6.0 limits nitrogen fixation and alfalfa yield. In these low pH areas, lime may be needed to increase soil pH. A soil test to determine alfalfa lime requirements (SMP buffer test) will indicate the lime application rates needed for low pH soils. For more information on this test, contact a soil testing lab (Daniels 2005) and see Oregon State University (Hart 1990) and University of Idaho (Mahler 1994) Extension bulletins on lime materials.

Many inland Pacific Northwest soils have become acidic (pH less than 7.0) due to long-term use of ammonium-based nitrogen fertilizer. Often these acidified soils have higher pH subsoil. When this situation exists, deep tillage can mix the topsoil and subsoil and delay the need for lime application.

Nitrogen (N)

Fortunately, alfalfa obtains most of the nitrogen it needs from the atmosphere through a symbiotic association with rhizobia (*Sinorhizobium meliloti*) bacteria that inhabit nodules in the alfalfa root system. Successful conversion of atmospheric nitrogen to a form usable by alfalfa ("fixation") depends on the presence of rhizobia in soil or inoculated seed, suitable soil pH (discussed above), and nutrient availability—particularly molybdenum, copper, and cobalt (discussed later).

Rhizobia require a source of energy (carbohydrate) from alfalfa. This comes at some cost to the plant, so alfalfa preferentially uses ammonium- and nitrate-nitrogen in the soil, if available, rather than fixing its own nitrogen. Nitrogen fixation is, however, a very cost-effective way to obtain nitrogen. Given the high nitrogen content of alfalfa (Table 1), fertilizing stands with nitrogen is seldom economical. For long-term production, correcting the underlying problem that is limiting fixation or shifting to non-legume (grass) production is normally more economical than fertilizing alfalfa with nitrogen.

Alfalfa is deep-rooted and drought-tolerant, making it well-suited for nitrogen uptake. The crop is commonly used to dispose of waste nitrogen from a variety of industries. At 50–70 lb per ton of hay, alfalfa removes more nitrogen than almost any other crop. When nitrogen is supplied via wastewater or manure, alfalfa preferentially absorbs nitrogen from the soil rather than fixing it from the atmosphere. A reasonable nitrogen application rate for disposal situations is 80% of the nitrogen removed by the hay crop. Fertilizing alfalfa with nitrogen may increase nitrate in the hay, so monitoring is helpful to curtail this problem if necessary.

Phosphorus (P)

Phosphorus is an important nutrient in alfalfa production with mild to moderate deficiencies commonly delaying maturity and limiting hay yield. Visual symptoms (Figure 1) can be difficult to recognize since they also resemble drought stress and certain diseases. Also, visual symptoms may not be apparent until deficiencies become severe enough to significantly reduce yield and allow grassy weeds to encroach on the stand.

Soil testing is a reliable way to diagnose phosphorus deficiency before it causes major yield reductions. Samples should be collected in late fall or early spring when alfalfa is dormant. Soil samples collected in-season will have lower test levels as a result of active absorption by growing plants and the relatively slow release of plant-available phosphorus from soil minerals. Tissue testing can also be used to diagnose phosphorus deficiencies during the growing season. Guidelines for phosphorus and other important alfalfa nutrient concentrations are summarized in Table 2. Soil or tissue testing for phosphorus should be done annually in irrigated systems and every 2–3 years in dryland systems to monitor nutrient levels.

Phosphorus recommendations based on soil test results are summarized in Table 3. For new stands, apply the amount of P_2O_5 specified in Table 2 plus enough additional P_2O_5 for 2 years of production based on expected yields and estimated crop removal (Table 1). Phosphorus movement in soil is very limited, so extra phosphorus applied during or prior to stand establishment will be available in future years.

Soil Testing for Alfalfa

It is difficult to generalize about the location and occurrence of specific nutrient deficiencies. Soils are inherently variable due to geologic processes and historic crop yields and nutrient applications. Some irrigation water sources also add nutrients to soil. For these reasons, soil testing is necessary to determine which nutrients are needed and in what amounts. Soil testing also provides important information on soil pH, salinity, and other conditions that may influence alfalfa growth. Common sampling depths for alfalfa are the surface 0–6 inches for lime requirements and 0–12 inches for most nutrients and soil pH. See the reference section at the end of this guide for information on where to send soil samples for analysis (Daniels 2005).

If a field will be fertilized as one unit, collect a minimum of 20 soil cores from representative locations throughout the field and combine these for the sample. This composite sampling technique provides a field average measure of soil properties. (If you are concerned about unusual or unrepresentative areas, collect cores from these separately and clearly distinguish via labeling.)

An alternative sampling approach is to divide a field into management units based on knowledge of variability in soil properties and yield potential. However, this approach is only warranted if you have the ability to manage units within a field separately. For example, you could separate a field into 2–3 management units based on slope, drainage, and/or soil type. Sample each management unit separately by collecting cores from several locations within the unit. Fertilize each unit according to the soil test results.

Additional information on soil sampling strategies can be found in publications listed at the end of this guide (Staben et al. 2003, Summers and Putnam 2008).

When possible, incorporate fertilizer into the surface 3–5 inches of soil with light tillage prior to establishing a new stand so that phosphorus will still be available to the plant when the soil surface dries.

Table 2. Interpretations of tissue tests for nutrient concentrations in alfalfa sampled at first bloom[1,2].

Nutrient	Critical concentration for sufficiency	Concentration including excess
Nitrogen (N)	3–4% 4–5%	
Phosphorus (P)	0.20–0.25% 0.25–0.35%	
Potassium (K)	2.0–2.5% 2.5–3.5%	above 3%[3] above 4%
Sulfur (S)	0.20–0.25% 0.25–0.30%	
Boron (B)	20 ppm 20–40 ppm	above 200[4] above 200
Manganese (Mn)	15 ppm 30–50 ppm	125–250
Iron (Fe)	40 ppm 40–100 ppm	
Zinc (Zn)	12 ppm 20–70 ppm	
Copper (Cu)	5 ppm 5–25 ppm	
Molybdenum (Mo)	0.8 ppm[5] 1–5 ppm[5]	above 10[6] above 10

[1]Correct insufficiencies in a manner similar to correcting low soil test results for these nutrients.
[2]The first concentration listed per nutrient corresponds to the whole plant top, while the second corresponds to the top 1/3 of the plant.
[3]Excess potassium may aggravate milk fever in “close-up” cows, hyperkalemic periodic paralysis in genetically susceptible horses, and winter tetany in beef cows.
[4]Tissue concentrations of boron above this level indicate plant toxicity, which may reduce yield.
[5]When a molybdenum tissue test indicates deficiency, this nutrient can be applied as a seed treatment at a maximum rate of 1 oz/acre or broadcast at 1–2 oz/acre.
[6]High molybdenum may cause secondary copper deficiency in ruminants. The ratio of copper to molybdenum should be above 2.

Supplemental applications of phosphorus made to established stands should be based on soil and/or tissue tests. Broadcast applications of dry phosphorus fertilizers are most effective when made in the fall or early spring to allow time for the phosphorus to dissolve before active growth begins. In furrow-irrigated systems, fall application of phosphorus is more important if dry forms are used since winter moisture is necessary to dissolve fertilizer pellets stranded on the beds. Fluid phosphorus forms are preferred for in-season applications to actively growing stands.

Tissue Testing for Alfalfa

Tissue testing is an effective way to directly monitor the nutrient status of alfalfa and diagnose nutrient-related problems. For certain elements like molybdenum where no soil test is available, tissue testing is the only way to accurately determine whether the nutrient is present in sufficient quantities that yield quality alfalfa.

Diagnosis of a nutrient deficiency with tissue testing may necessitate subsequent soil testing since insufficient databases exist from which to develop fertilizer recommendations based on tissue tests alone. One good source to check for tissue test-based fertilizer recommendation information is Summers and Putnam 2008.

Both growth stage and plant parts are important when sampling alfalfa tissue (Table 2). Gather sample tissues by removing the appropriate plant part at first bloom in 10 locations throughout a field, and then combine. Keep tissue samples cool and transport them to a testing lab as soon as possible (Daniels 2005). When you get the results, compare the tissue nutrient levels to the critical values given in Table 2 to determine if your alfalfa's nutrient concentrations are sufficient.

Another way to diagnose nutrient deficiencies in your alfalfa is to collect paired tissue samples where one composite sample is from a good section of a field and another, separate composite is from a problem area. Clearly label each composite and send to a lab. Compare the findings for the problem area with the critical levels in Table 2 as well as what the lab found for both the good and problem areas to identify major differences.

Fluids can be applied through an irrigation system (fertigation), in surface bands spaced 12 inches or less apart with stream nozzles, or sprayed uniformly on fields using a fan nozzle.

Several high analysis (high P_2O_5 concentration) sources of phosphorus fertilizer are available, including dry triple superphosphate (0-45-0; 45% P_2O_5 by weight), monoammonium phosphate (11-52-0; 52% P_2O_5 by weight), diammonium phosphate (18-46-0; 46% P_2O_5 by weight), fluid ammonium polyphosphate (10-34-0 or 11-37-0, 34 or 37% P_2O_5 concentrations on a weight basis), and phosphoric acids (various P_2O_5 concentrations). High analysis forms are typically the least expensive fertilizers per unit of phosphorus. Other, lower analysis phosphorus fertilizers are available such as 16-20-0-13S (20% P_2O_5), but the extra cost for nitrogen in the material is often not warranted and the sulfur concentration is too high to make this a practical phosphorus fertilizer source. Numerous comparisons indicate that when topdressed at the same rate of P_2O_5, the fertilizer sources mentioned above are equally effective. Therefore, it is most economical to select a phosphorus source based on local availability, ease of application, and cost per unit of P_2O_5. Rock phosphate is insoluble and is not recommended as a source of phosphorus for alfalfa.

Potassium (K)

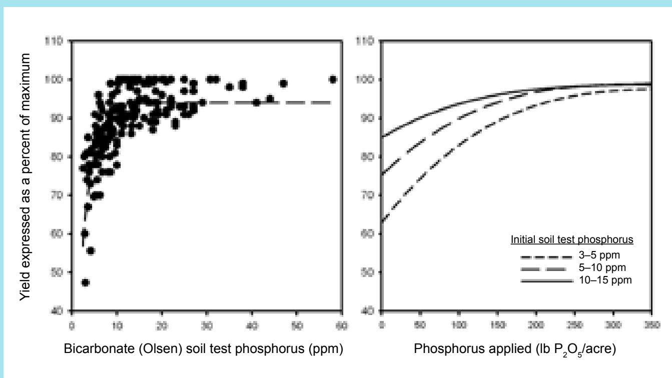
After phosphorus, potassium is often the second most limiting nutrient in alfalfa production. Moderate potassium deficiencies can limit yields and reduce stand life. Visual symptoms (Figure 2) are easy to recognize but may not become apparent until deficiencies are severe enough to significantly reduce yield and shorten stand life.

Figure 2. Potassium deficiency in alfalfa is represented by necrotic spots on the outer margins of young leaves and thin, declining stands.

Predicting Alfalfa Responses to Phosphorus Fertilizer

Soil test interpretations and fertilizer recommendations are based in part on the probability of obtaining a yield response to fertilizer application as well as the magnitude of that yield response. The probability and magnitude of a response are generally higher when initial soil test values are lower; however, both depend on many other factors that influence yield, including water availability, stand quality, and pest pressures.

The graph below and to the left illustrates an example of relative alfalfa yields at soil test phosphorus levels using the Olsen (sodium bicarbonate) extraction procedure. Relative yield is used here in order to combine data from a large number of studies and identify trends. According to the lefthand graph, yield approaches 95% of the maximum for most locations when the Olsen soil test for phosphorus results in 15 ppm. The graph below and to the right shows an example of relative alfalfa yield responses to phosphorus fertilizer application when the initial soil test is very low (3–5 ppm), low (5–10 ppm), or moderate (10–15 ppm). As expected, the yield response is greatest and the most fertilizer phosphorus is required to reach maximum yield when the initial soil test indicates phosphorus is very low.



Data from Koenig et al. 1999

The phosphorus fertilizer recommendations summarized in Table 3 are based on initial soil test values and yield potentials for irrigated and dryland production situations. There is some uncertainty in developing these recommendations since individual soil types vary in their ability to supply phosphorus and yield is influenced annually by more factors than just the soil test level. However, attempts to further refine fertilizer recommendations are not justified given the uncertainty and variability in yield responses to soil test phosphorus levels and fertilizer rates. Growers are encouraged to use the recommendations in this document as a guide as well as monitor their alfalfa yields and soil and plant tissue concentrations to evaluate the success of their fertilizer programs.

Alfalfa removes large quantities of potassium from soil (Table 1). In areas with a long history of alfalfa production, soil potassium reserves are commonly depleted. Soil testing is a reliable way to diagnose potassium deficiency before it causes significant yield reductions. The standard sampling depth for potassium is 0–12 inches. Samples should be collected in late fall or early spring when alfalfa is dormant. Soil samples collected in-season will have lower test levels as a result of active absorption by growing plants and the relatively slow release of plant-available potassium from soil minerals. Tissue sampling can be used to diagnose potassium deficiencies in-season. In areas with a history of potassium deficiency, soil or tissue sampling for potassium should be done annually to monitor nutrient levels.

Potassium recommendations based on soil test results are summarized in Table 4. Alfalfa will absorb more potassium than it needs for optimum yields. This tendency for "luxury consumption" may result in the harvest of

Table 3. Soil test-based phosphorus fertilizer recommendations for irrigated and dryland alfalfa.

Table 3a. Per acre recommendations based on P soil testing.

Soil test for phosphorus[1]		P_2O_5[2] recommendation	
Olsen (bicarbonate) method	Morgan (accetate) method	Irrigated	Dryland
—mg/kg of soil or ppm—		—lb P_2O_5/acre[3]—	
0–5[4]	0–3[4]	150–200	50–75
5–10	3–4	100–150	25–50
10–15	4–5	50–100	0–25
15–20	5–6	0–50	0
above 20	above 6	0	0

Table 3b. Per ton recommendations based on yield expectations and P soil testing.

Soil test for phosphorus[1]		P_2O_5[2] recommendation	
Olsen (bicarbonate) method	Morgan (accetate) method	Irrigated	Dryland
—mg/kg of soil or ppm—		—lb P_2O_5/acre[3]—	
0–5[4]	0–3[4]	20–30	15–20
5–10	3–4	15–20	10–15
10–15	4–5	8–15	0–10
15–20	5–6	0–8	0
above 20	above 6	0	0

[1]Soil testing for phosphorus is based on a 0–12-inch sample depth. Olsen is the preferred extract method. While some labs use Morgan, it is the least reliable extract method and should be avoided. Interpretations are given here only because some testing labs still use the Morgan procedure. In southern Idaho, soil lime content is also included in the interpretation of an Olsen soil test for phosphorus (Stark et al. 2002).
[2]Fertilizer labels are expressed in % P_2O_5. To convert P_2O_5 to P, multiply by 0.44.
[3]Recommendations in Table 3a assume a 6–8 ton/acre yield for irrigated and a 2–3 ton/acre yield for dryland alfalfa.
[4]Low soil test levels severely limit yield. Test soil and apply phosphate annually until levels are adequate.

Table 4. Soil test-based potassium fertilizer recommendations for irrigated and dryland alfalfa.

Table 4a. Per acre recommendations based on K soil testing[3].

Soil test for potassium	K_2O recommendation[2]	
Olsen (sodium bicarbonate), Morgan (acetate), or equivalent exchangeable method[1]	Irrigated	Dryland
—mg/kg of soil or ppm—	—lb K_2O/acre[3]—	
0–50[4]	200–300[5]	50–100
50–100	100–200	0–50
100–150	50–100	0
150–200	0–50	0
above 200	0	0

Table 4b. Per ton recommendations based on yield expectations and K soil testing.

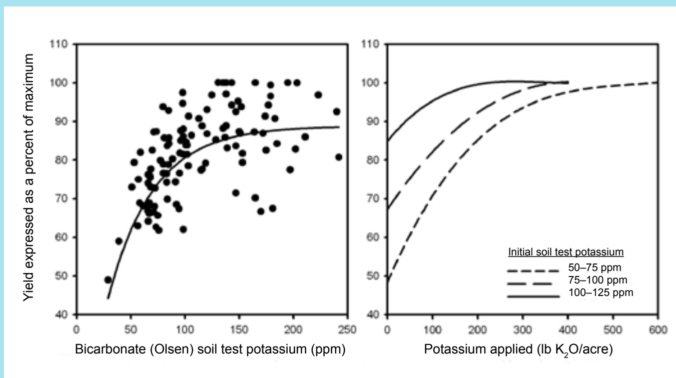
Soil test for potassium	K_2O recommendation[2]	
Olsen (sodium bicarbonate), Morgan (acetate), or equivalent exchangeable method[1]	Irrigated	Dryland
—mg/kg of soil or ppm—	—lb K_2O/acre[3]—	
0–50[4]	30–40[5]	20–30
50–100	15–25	0–20
100–150	10–15	0
150–200	0–5	0
above 200	0	0

[1]Soil testing for potassium is based on a 0–12-inch sample depth. These 2 extract methods are commonly used for potassium. Both are accurate across a range of soil conditions and the results and interpretations are identical.
[2]Fertilizer labels are expressed in % K_2O. To convert K_2O to K, multiply K_2O by 0.83.
[3]Recommendations in Table 4a assume a 6–8 ton/acre yield for irrigated and a 2–3 ton/acre yield for dryland alfalfa.
[4]Low soil test levels severely limit yield. Test soil and apply potash annually until levels are adequate.
[5]Split K_2O applications by applying 50% in early spring and 50% after the second cutting.

Predicting Alfalfa Responses to Potassium Fertilizer

Similar to phosphorus, potassium fertilizer recommendations at a given soil test level are based in part on the probability of obtaining a yield response and the magnitude of that response. The graph below and to the left illustrates an example of relative alfalfa yield at a soil test potassium level using Olsen (sodium bicarbonate) or acetate extract procedures. Again, relative yield is used in order to combine data from a large number of studies and identify trends. The relationship is not as clear as for phosphorus. Yield approaches 90% of the maximum for most locations when soil test potassium is 150 ppm.

The graph below and to the right shows an example of relative alfalfa yield responses to potassium fertilizer application when an initial soil test result is very low (50–75 ppm), low (75–100 ppm), or moderate (100–125 ppm). As with phosphorus, the lower the level of potassium an initial soil test indicates, the greater the yield response will be but more fertilizer potassium required to reach maximum yield.



Data from Koenig et al. 2001

high potassium hay and accelerated removal of potassium from soil. For this reason, large applications to meet multiple years of potassium needs are not recommended; annual applications above 200 lb K_2O/acre should be split between early spring and mid-season dates.

Several high analysis sources of potassium fertilizer are available, including dry potassium chloride (0-0-60; 60% K_2O by weight), potassium sulfate (0-0-50-18S; 50% K_2O by weight), and potassium-magnesium sulfate (0-0-22-18S, 22% K_2O by weight). Fluid forms of potassium fertilizer also exist, but these contain less potassium per pound and are commonly more expensive than dry sources. High analysis (high K_2O concentration) forms are typically the least expensive fertilizers per unit of potassium. As with phosphorus, multiple comparisons indicate that when applied at the same rate of K_2O, the materials mentioned above are equally effective. Therefore, it is most economical to select a potassium source based on local availability, ease of application, and cost per unit of K_2O. Irrigation water may also contain potassium; to estimate, analyze a sample of irrigation water and multiply the parts per million of potassium by 3.28 to convert to pounds of K_2O per acre-foot of water.

Sulfur (S)

Sulfur deficiency in alfalfa is common in areas with high rainfall, as well as sandy soils and when irrigation water with low sulfur concentrations is used. The effects of sulfur deficiency (Figure 3) resemble those of nitrogen deficiency, except that sulfur deficiency symptoms appear on the newest foliage first. A

Figure 3. Symptoms of sulfur deficiency in alfalfa include short plants, thin stands, and light green color. The main photo shows a sulfur Z-strip applied to a sulfur-deficient field of alfalfa. The inset photo illustrates alfalfa that is sulfur-deficient (right) and sulfur-fertilized (left).

deficiency in sulfur for alfalfa results in reduced yield, crude protein content, and feed value.

The soil test for sulfur is somewhat unreliable due to the mobility of the plant-available form of sulfur (sulfate) and inability of the soil test to estimate sulfur release from soil organic matter. Most soil tests report sulfur in the sulfate (SO_4-S) form. Interpretations of sulfate-sulfur soil test values are summarized in Table 5. Tissue testing can also be used to monitor the sulfur status of alfalfa. Irrigation water from return flows and certain groundwater wells may contain substantial sulfur, so analysis of these sources may be warranted. To estimate this contribution, multiply parts per million sulfate-sulfur (SO_4-S) in irrigation water by 2.72 to convert to pounds of sulfur per acre-foot of water applied.

Common sources of dry sulfur fertilizer include ammonium sulfate (21-0-0-24S; 24% sulfur), potassium sulfate (0-0-50-18S; 18% sulfur), potassium-magnesium sulfate (0-0-22-18S, 18% S), gypsum (0-0-0-17S, 17% sulfur), and elemental sulfur (0-0-0-90S; 90% sulfur). Fluids such as potassium thiosulfate (0-0-25-17S, 17% S), potassium polysulfide (0-0-22-23S, 23% S), ammonium thiosulfate (12-0-0-26S, 26% S), and ammonium polysulfide (20-0-0-40S, 40% S) are also available. Many of these fluids can be mixed with irrigation water and applied in-season. Undiluted fluid forms of sulfur will burn tissue if applied to actively growing alfalfa, but are generally safe when applied to dormant alfalfa.

Micronutrients

Zinc, molybdenum, and boron deficiencies occur relatively frequently in alfalfa. Zinc deficiency is more common in high pH soils. Molybdenum and boron deficiencies are more common in high rainfall areas with low pH soils. Soil or tissue testing can be used as a guide to zinc and boron deficiencies, although the boron test has not proven reliable. Copper and manganese deficiencies are very rare in alfalfa. Micronutrient soil (Table 6) or tissue testing can be used to determine if copper fertilization is necessary. Manganese deficiency should be diagnosed with a tissue test. There is no soil test for molybdenum, so it is best to rely on tissue testing to diagnose a deficiency. A very small amount of cobalt is needed for nitrogen fixation; however, there is no evidence that cobalt deficiency is a problem and no soil tests or critical tissue values for alfalfa are available.

Sources of zinc, iron, copper, and manganese include metal salts and oxides (e.g., zinc sulfate or zinc oxide) and chelated forms. Chelated forms are more available to alfalfa than salts or oxides and can generally be applied at lower rates to correct deficiencies. However, chelated forms cost more than salts or oxides. Sodium

Table 5. Soil test-based sulfur fertilizer recommendations for irrigated and dryland alfalfa.

Table 5a. Per acre recommendations based on S soil testing.

Soil test for sulfur in the sulfate form (SO_4–S)[1]		Sulfur recommendation	
		Irrigated	Dryland
mg/kg of soil or ppm	—lb/acre—	—lb sulfate or sulfide-sulfur/acre[2,3]—	
0–5	0–20	25–35	10–20
5–10	20–40	15–25	0–10
10–15	40–60	10–15	0
above 15	above 60	0	0

Table 5b. Per ton recommendations based on yield expectations and S soil testing.

Soil test for sulfur in the sulfate form (SO_4–S)[1]		Sulfur recommendation	
		Irrigated	Dryland
mg/kg of soil or ppm	—lb/acre—	lb sulfate or sulfide-sulfur/ton of expected yield[2]	
0–5	0–20	3–5	2–4
5–10	20–40	2–3	0–2
10–15	40–60	0–2	0
above 15	above 60	0	0

[1]Soil testing for sulfur is based on a 0–12-inch sample depth. Various extract methods are used for sulfur, but the results and interpretations are identical. All soil test sulfur methods are subject to limitations described in the sulfur section of the text.
[2]Sulfate- and sulfide-sulfur forms are rapidly available to the plant and should be used to correct a deficiency. Combining these recommendations with 50–100 lb of elemental sulfur (0-0-0-90 S, a slow release form) will provide sufficient sulfur for the current year of production plus an additional 10–20 tons of hay production over the next 2–3 years.
[3]These recommendations assume 6–8 ton/acre yield for irrigated and a 2–3 ton/acre yield for dryland alfalfa.

Table 6. Micronutrient soil test concentrations, interpretations, and recommendations for alfalfa[1].

Micronutrient	Low	Marginal	Adequate
	soil test concentration in mg/kg or ppm[2]		
Zinc	below 0.8	0.8–1.0	above 1.0
Copper	below 0.2	—	above 0.2
Manganese	Rely on tissue testing to diagnose a deficiency.		
Molybdenum	Rely on tissue testing to diagnose a deficiency.		
Boron (coarse-textured soils)[3]	below 0.2	0.3–0.4	0.5–1.0
Boron (fine-textured soils)[4]	below 0.3	0.4–0.8	0.9–1.5
Recommendation	Apply 10 lb of zinc and 2 lb of copper or boron.	Apply 5 lb of zinc and 1 lb of copper or boron.	NA

[1]Soil test levels are based on a 0–12-inch sample depth.
[2]The soil test extraction method for zinc and copper is abbreviated DTPA (Diethylene triamine pentaacetic acid). Boron is extracted with hot water.
[3]sand, loamy sand, sandy loam
[4]loam, silt loam, clay loam, clay

or calcium salts of boron and molybdenum are highly soluble and available to plants.

Additional considerations

Fertigation

Application of liquid fertilizers via irrigation is an efficient and convenient way to supply nutrients to alfalfa, including during the growing season. Liquid sources of phosphorus, potassium, sulfur, and micronutrients are available. It is important to carefully compare the cost and convenience of using liquid sources vs. dry fertilizer materials. Also understand that some fluid fertilizer sources can precipitate in irrigation lines and plug orifices, while others are corrosive. Seek advice from your fertilizer and irrigation system dealers on injecting specific chemicals into your system.

Manure and alfalfa

Livestock manures contain large quantities of phosphorus and potassium, and smaller amounts of all other nutrients alfalfa requires. When applied to grain or other crops in a rotation, manure is an efficient way to build soil nutrient levels before reestablishing alfalfa. Manure can also be applied to dormant alfalfa, but may increase weed problems in established alfalfa stands by supplying weed seeds and high rates of nitrogen that stimulate grassy weed growth.

Potassium and animal health

The high potassium content of alfalfa hay is related to milk fever in dairy cows and hyperkalemic periodic paralysis in genetically susceptible horses. Potassium levels in hay can be moderated by limiting potassium fertilizer to anticipated crop use and available soil potassium as determined by soil testing. Not surprisingly, alfalfa harvested from fields known to have low soil test potassium will be lower in potassium content than hay harvested from fields with adequate soil potassium. Delaying alfalfa harvest until early to mid-bloom also reduces hay potassium content. Rain that occurs while the crop is still in the windrow causes potassium to leach from hay.

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