Alfalfa Nutrient Management Guide

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Introduction

Alfalfa is the most important field crop grown in Utah because of our dry climate, the quality of feed produced, and economic return to farm businesses. Utah growers produce roughly 2 million tons of alfalfa hay per year, averaging 4.1 tons per acre in 2022 (National Agricultural Statistics Service [NASS], 2024). Much of the alfalfa grown in Utah feeds dairy and beef cattle, with some being exported. Proper nutrient management is key to maintaining high yields, quality, and stand longevity for profitable alfalfa production.

As alfalfa grows, it uses nutrients from the soil and air to form new tissue. Table 1 displays the amount of nutrients each ton of alfalfa removes from the soil during harvest. The nutrients that alfalfa and other plants remove from the air are relatively unlimited, but nutrients from the soil are limited by their concentration in the soil and root depth. Fertilizers and soil amendments are often used to supplement soil nutrients to supply the crop with the quantities needed for optimal growth. Alfalfa nutrient needs and fertilizer recommendations are determined by current soil test results, yield potential, field history, and soil nutrients being removed by the crop. In Utah, phosphorus (P) is the nutrient most often recommended in the highest quantities for alfalfa production. Several other nutrient deficiencies have been reported, but it greatly depends on field location, soil type, and field fertility history. Nutrient deficiencies can negatively impact crop yield, quality, economics, and stand life.

Highlights

- Proper nutrient management is key to maintaining high yields, quality, and stand longevity for profitable alfalfa production.
- Alfalfa nutrient needs and fertilizer recommendations are determined by current soil test results, yield potential, field history, and soil nutrients being removed by the crop.
- Tissue tests can be the most accurate way to diagnose a micronutrient deficiency in alfalfa.
- In Utah, phosphorus (P) is the nutrient most often recommended in the highest quantities for alfalfa production.
- By the time that visible symptoms of nutrient deficiencies appear, yield, quality, and economic losses have already occurred.
- Fertilizer applications can greatly improve crop yield and quality, and in turn, greatly increase economic returns.

Table 1. *Average Nutrient Concentrations and Removal by Alfalfa During Harvest*

Nutrient	Dry matter concentration	Removal per ton of hay
Potassium	0.85–4.65% K_2O	55 lbs K_2O
Phosphate	0.42–0.81% P_2O_5	12 lbs P_2O_5
Sulfur	0.3% S	4–6 lbs S
Zinc	0.002% Zn	0.04 lb Zn
Boron	0.003% B	0.05 lb B

Notes. The potassium, phosphate, and sulfur concentrations and removal rates are averages from yield data and elemental analyses for alfalfa forage samples collected in Utah fields during 2020–2023. Boron and zinc rates are from previously published reports. All removal rates are for dry matter yields calculated at 0% moisture. These values are estimates and should be validated for specific field conditions.

Approaches to Fertilization

There are several different strategies used when making fertilizer recommendations (Fig. 1), often resulting in large differences in recommended rates (Macnack et al., 2017). The following strategies apply mainly to immobile nutrients such as P and potassium (K) but not mobile nutrients like nitrogen (N) that have the potential to leach from soil.

1. **Sufficiency -** The goal of this strategy is to ensure that the plant has the nutrients required to grow that season. These are provided by fertilizer or amendments to supplement whatever the soil is not able to provide. Soil test values are interpreted as fitting within categories that determine the amount of fertilizer that will need to be added. The soil test values that define these categories are determined through yield response trials that determine critical values where the addition of fertilizer no longer increases yield. This approach is most often used by universities to determine fertilizer recommendations; it is also often the most conservative approach. It maximizes yield while minimizing annual nutrient inputs.
2. **Maintenance** - The goal of this strategy is to maintain a consistent and adequate level of nutrients within the soil. Fertilizer is applied to supply the crop with what it needs, but also at rates high enough to replace the nutrients taken from the soil. This approach is also regularly used by universities, but often recommends higher rates than sufficiency.
3. **Buildup** - The buildup approach is used in cases where the goal is to build the concentration of a nutrient within the soil to the point where it will not be limiting. Usually, over several years, fertilizer is applied at a rate higher than what is needed by the crop to build up a reserve of the nutrient within the soil. Annual buildup applications spread the cost over several years rather than the expense of a single, large application.

Figure 1. *Fertilization of Alfalfa in Rich County, Utah, in 2023*

Photo credit: Matt Yost

4. **Combination** - Some universities and laboratories determine fertilizer recommendations using a combination of the buildup and maintenance approaches. This strategy is often used with immobile nutrients such as potassium and phosphorus to spread the applications out over time rather than a singular, large application. Once the soil nutrient surpasses the critical soil test level, the fertilizer recommendations are then based on maintenance. This approach also minimizes the risk of nutrient deficiencies, while allowing farmers to postpone or skip fertilization when prices are high or quantities are limited.

Nitrogen

Alfalfa is a legume and has nodules on the roots that contain symbiotic nitrogen-fixing bacteria that normally provide the plants with all the N that they need for growth. Research has shown that when establishing a new stand of alfalfa, a small rate (20–50 pounds per acre) can provide alfalfa with necessary N before the bacterial symbiosis develops (Koenig et al., 2009; Undersander et al., 2011). Applications above 50 pounds N per acre during stand establishment can inhibit bacterial symbiosis. Nitrogen is not recommended on established alfalfa stands. While it is not needed, be aware that N is frequently applied on alfalfa as a part of fertilizer blends targeting P applications, such as monoammonium phosphate (11-52-0) and diammonium phosphate (18-46-0). Triple-super-phosphate (0-45-0) is a phosphate source that does not contain nitrogen, but it is usually more expensive per unit of P and is not available in many locations.

Phosphorus

Phosphorus is one of the most commonly deficient nutrients in alfalfa, especially in high yield cropping systems. Alfalfa plants with P deficiency will have reduced growth with small leaves. Leaflets often fold together, and leaves appear dark green or purple. Stems may be red or purplish. Due to similarities to other plant-stress symptoms, P deficiencies are extremely difficult to identify visually.

Phosphorus is an important component for promoting root growth, metabolic processes, and energy production. Deficiencies result in poor stand establishment, delayed maturity, and reduced yields (Koenig et al., 2009). Soil testing is the most reliable and efficient way to diagnose and treat P deficiencies before crop stress occurs (Table 2). Regular soil testing is the foundation of a fertilizer program that can be supplemented with later tissue testing.

How much P to apply

Utah State University (USU) guidelines (and from most public and university labs) are based on a “sufficiency” approach as described above. Following this approach, when soil test phosphorus is **less than 15 parts per million (ppm)** (based on a 12-inch-deep soil sample and Olsen extraction of phosphorus), the likelihood of an alfalfa yield response to fertilizer P is high. Soils that test **above 15 ppm** have a low likelihood of responding to P from fertilizer or amendments.

How, when, and what P to apply

Phosphorus is an immobile nutrient with limited movement through the soil in the root zone, making it important to incorporate at planting, if possible (Fig. 2). A study in Wisconsin found that at low to medium soil test levels, incorporated P was more than twice as efficient as top-dressed P (Kelling, 2000). This limited movement also makes it feasible to apply extra P prior to stand establishment because it will be available in future years. Quantities for the first 1–3 years can be applied and incorporated 6–12 inches deep. Supplemental applications should be based on soil or tissue tests. In established alfalfa stands, broadcast applications of dry P fertilizer are most effective in the fall or early spring.

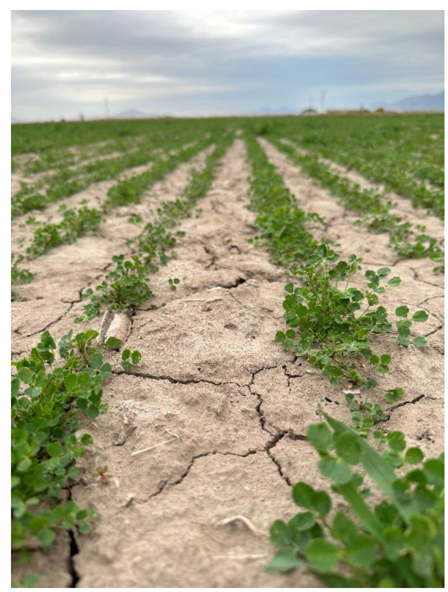

Figure 2. *Incorporating P and K Fertilizer Is Recommended Before Alfalfa Planting*

Photo credit: Matt Yost

Select fertilizer based on availability, cost per unit P_2O_5, and application method. Some of the most common sources of P fertilizer are: monoammonium phosphate (11-52-0; 52% P_2O_5), diammonium phosphate (18-46-0; 46% P_2O_5), liquid phosphoric acid (varying P_2O_5 concentrations), liquid ammonium phosphate (10-34-0, 34%), and triple superphosphate (0-45-0; 45% P_2O_5). Manure, compost, and other organic soil amendments can be a great way to supply P. They also contribute significantly to increasing soil organic matter content, which can increase soil tilth and water-holding capacity. Be sure to sample and test these amendments (Miller et al., 2023) and measure application rates to direct and quantify P inputs.

Table 2. *Phosphorus Recommendations for Alfalfa Production*

Soil test phosphorus (ppm)	Recommendation (lb P_2O_5/acre)
0–4*	200–250
5–7*	150–200
8–10	100–150
11–15	50–100
>15	0

Notes. *Low soil tests levels can severely limit yield. Test soil annually or often until levels are adequate. Recommendations are based on a 12-inch soil sample depth and sodium bicarbonate (Olsen method) soil extractant.

Potassium

Potassium (K) is often the second most limiting nutrient in alfalfa production because large amounts of K are removed from the soil (Table 1). Alfalfa deficient in K will often have white and/or yellow spots around the edge of leaves, starting with lower leaves. By the time visual symptoms appear, substantial yield loss has likely occurred. Potassium is important to physiological processes in alfalfa plants, including the enzyme activation, carbohydrate synthesis and degradation, protein synthesis, and the opening and closing of stomata (Lissbrant et al., 2009).

How much K to apply

Many Utah soils are naturally high in K and do not require potassium fertilizer or amendments. Based on the sufficiency approach, if a need for K is identified (soil test K **less than 150 ppm**), it is likely that annual applications will be required to maintain adequate levels. When soil test K (STK) is **greater than 150 ppm**, there is a low likelihood that additional potassium will increase yield.

How, when, and what K to apply

Potassium is a more mobile nutrient than P and can be topdressed to meet alfalfa nutrient needs (Table 3). Topdressing following the first cutting is sometimes recommended to stimulate growth in the second and third cutting or in the early fall to increase winterhardiness.

Large, multiyear applications of K are not recommended since alfalfa will absorb more K than needed for optimal growth. Luxury consumption may result in high potassium hay, contributing to milk fever in dairy cattle and accelerate K removal from soil. Split applications can be effective for meeting plant K needs and limiting luxury consumption if large amounts of K (above 300 pounds per acre) are to be applied (Malher, 2005). If you suspect luxury consumption of K, monitor forage tissue K levels (Undersander et al., 2011).

The most common sources of K fertilizer are potassium chloride (KCl), which is often termed “potash” (0-0-60; 60% K_2O), potassium sulfate (0-0-50; 50% K_2O), and liquid potassium (various K2O concentrations). Animal manure or compost can also be a source of K for plants; contents will vary but typically range from 1%–2% dry matter of K_2O.

Table 3. *Potassium Recommendations for Alfalfa Production*

Soil test potassium (ppm)	Recommendation (lb K_2O/acre)
0–50*	180–220
50–70	140–180
70–100	100–140
100–150	60–100
>150	0

Notes. *Low soil test levels can severely limit yield. Test soil annually or often until levels are adequate. Recommendations are based on a 12-inch sample depth and sodium bicarbonate (Olsen method) soil extractant.

Sulfur

Sulfur (S) is important for protein synthesis, chlorophyll formation, and enzyme activity in alfalfa. Deficiencies will limit crop growth and lower crude protein content. Alfalfa that is deficient in S will express symptoms such as light green, spindly stems, and weak growth. These can be similar symptoms of N deficiency, so careful diagnosis is needed. Sulfur deficiency, although not a frequent occurrence, has been documented in some locations throughout Utah. Generally, sandy, low-organic-matter soils in areas with irrigation water low in sulfur are subject to sulfur deficiency. Early seasonal S deficiency is often seen in cool, wet spring conditions. In these cases, as the soil warms and dries, the deficiency resolves itself as S becomes more available. Severe sulfur deficiency significantly reduces yield and lowers alfalfa quality.

How much S to apply

Soil tests can be inaccurate or unreliable for S due to the mobility of the plant-available form of sulfur (sulfate or SO_4^{2-}) and the inability for soil tests to accurately estimate sulfur release from organic matter (Ketterings et al., 2011). Tissue testing can be a more accurate way to assess S levels in alfalfa, but fertilizing based on this method alone increases the risk of deficiency. If visual deficiency symptoms are observed, loss of yield and quality has already occurred. Alfalfa uses large amounts of sulfur, and sulfate-sulfur soil test values **less than 8 parts per million (ppm)** can indicate the need for sulfur fertilization (10-20 pounds S per acre). However, recent trials in Utah during 2022–2023 showed no response to S fertilizer at fields with soil test S below 8 ppm (Baker et al., 2024). This indicates that supplemental sulfur is likely not needed in many cases and that tissue levels should be carefully monitored for possible deficiencies.

Irrigation water can be a significant source of S because irrigation water in Utah can have high S content. In irrigation samples collected at 27 farms across Utah during 2021–2023, irrigation water had between 6–290 ppm sulfate and resulted in annual applications of 17–800 pounds of sulfate per acre-foot of water applied. High sulfur in irrigation may be the reason that responses to sulfur fertilization are rare.

How, when, and what S to apply

Sulfur can be applied anytime but is typically applied in the spring or fall in combination with other fertilizers. Common sulfur sources in Utah include gypsum (17% sulfur), elemental sulfur (0-0-0-90S; 90% sulfur), ammonium sulfate (21-0-0-24S; 24% sulfur), and potassium sulfate (0-0-50-18S; 18% sulfur). When products containing sulfur are applied as soil amendments, they are often applied in the fall so that they have time to become available over the winter season. Elemental sulfur is a slow-release form of sulfur, and this should be accounted for when planning application timing. Gypsum is an amendment for sodic soils (Barker et al., 2023) that can also provide S, so be sure to account for the S used to treat sodic soils when planning fertilizer applications as a soil fertility nutrient.

Micronutrients

Deficiencies of zinc, iron, copper, manganese, and boron are rare in alfalfa. Soil testing can determine if these micronutrients are needed (Table 4). Visual symptoms can often be confused with other nutrient deficiencies, which is why tissue tests are also used. Tissue tests can be the most accurate way to diagnose a micronutrient deficiency in alfalfa.

- **Zinc** is a critical component for metabolic processes and for tolerating excessively low or high soil moisture (Grewal & Williams, 2000). Alkaline soils, sandy soils, or those low in organic matter are more prone to deficiencies. Visual symptoms often start in the middle leaves and include stunted growth, yellowing of upper foliage, and necrotic spots and margins on the leaves. Zinc is the most common micronutrient deficient in Utah soils.
- **Iron** is used in producing chlorophyll and enzyme functions. Alkaline soils with high free calcium carbonate, low organic matter, and little topsoil are prone to iron deficiencies. Iron deficiencies are characterized by interveinal chlorosis progressing to fully white or yellow plants and slow plant growth (Westfall & Bauder, 2011).
- **Copper** is needed for chlorophyll production, respiration, and protein synthesis. Deficiencies are more common in alkaline, organic, and sandy or heavy soils. Copper deficiencies are characterized by wilting younger leaves, reduced growth, and leaves becoming a greenish-gray color (Manitoba-Agriculture, n.d.).
- **Manganese** is involved in several metabolic processes, and deficiencies are more common in soils with high pH and lime contents, sandy soils, and poorly draining soils. Symptoms of manganese deficiency include stunted growth, interveinal chlorosis, and reduced yield.
- **Boron** is important for cell wall formation and reproductive tissue (McCauley et al., 2011). Boron-deficient alfalfa often has stunted growth, poor flowering, yellow upper leaves, and rosetting of leaves.

How much to apply

Micronutrient fertilizer responses in alfalfa have been rare in Utah. Critical soil test values for zinc have been identified by USU, and these ranges are shown below (Table 4). For other micronutrients, recommendations from surrounding states are given (Koenig et al., 2009; Undersander et al., 2011). The critical levels for alfalfa in Table 4 are the same levels for most crops in Utah.

- If Zn, Mn, or Fe are low, **10 pounds per acre** are recommended and **5 pounds per acre** if levels are marginal.
- For Cu or B, rates of **2**–**3 pounds per acre** are recommended if soil test levels are low.

Recent research (2021–2023) in Utah on 12 farm fields has shown no alfalfa yield or quality response to micronutrients, even when soil test values are lower than the critical levels (Fig. 3). Thus, additional research is needed to further develop these critical soil test levels. Until that is developed, visual scouting for deficiency and tissue testing (Table 5) may be the best tools for finding the rare cases where micronutrients are needed.

Figure 3. *Alfalfa Micronutrient Fertilizer Trial Near Parowan, UT, Conducted 2021–2023*

Photo credit: Megan Baker

How, when, and what to apply

Micronutrient fertilizers can be applied before, during, or after the growing season, depending on the source and the level of deficiency. Correct deficiencies detected in the growing season as quickly as possible. Several granular and liquid products are available for each nutrient. Sulfate salts are common sources of Zn, Mn, Fe, and Cu in Utah. Foliar sprays containing a blend of micronutrients are also used, but due to high costs, they should only be used when deficiencies are diagnosed or in crops especially prone to deficiencies. Borax, sodium borate, and boric acid are common sources of boron. Liquid micronutrients often improve application uniformity because granular product rates can be low (5 to 10 pounds per acre), making it difficult to spread fertilizer prills evenly. Organic amendments often have diverse and high levels of micronutrients, so be sure to sample and test these materials to adjust fertilizer applications accordingly.

Table 4. *Micronutrient Soil Test Values in Parts Per Million (ppm) and Interpretations for Alfalfa*

Nutrient	Low	Marginal	Adequate
Zinc	<0.8	0.8–1.0	>1.0
Iron	<3.0	3.0–5.0	>5.0
Copper	<0.2	-	>0.2
Manganese	<1.0	-	>1.0
Boron	<0.25	0.25–0.5	>0.5

Note. Based on a 12-inch sample depth and DTPA extraction used for zinc, manganese, iron, and copper.

Soil Testing

Soil sampling before the growing season begins helps determine what the soil may provide and allows sufficient time to plan fertilizer applications and make profitable decisions. It allows for a proactive approach to fertilizer management that can be supplemented with in-season monitoring. Depending on intended fertilization timing, collect soil samples in the late fall or early spring when the alfalfa is dormant. In-season samples will have lower soil test P levels due to the plants actively absorbing the nutrient and the slow release of plant-available P from soil minerals (Koenig et al., 2009). Current guidelines in Tables 2–4 are based on soil samples collected to a 12-inch sample depth. This may be recalibrated to shallower depths in the future, but we currently recommend sampling to 12 inches. Find more details for soil sample collection and handling in USU Extension's fact sheet Soil Sampling Guide for Crops (Yost et al., 2023).

Tissue Testing

In-season tissue testing can determine nutrient levels or diagnose deficiencies. It is important to remember that by the time visual symptoms of deficiencies appear, yield loss has already occurred. Tissue testing is a direct way to monitor nutrient levels in plants and identify common trends for the crop.

Figure 4. *Test the Top 6 Inches of Alfalfa Tissue*

Photo credit: Megan Baker

Randomly collect a sample of 20–60 stems of the top 6 inches of new growth from across the field at the first bloom stage of growth, usually 10–30 plants (1–3 stems per alfalfa plant; Fig. 4). Keep tissue samples cool and transport or ship them to a testing lab as soon as possible. Tissue nutrient levels below the critical values given in Table 5 indicate that supplemental fertilization may be needed.

If samples are collected at the one-tenth bloom stage, nutrient concentrations will often be roughly 10% lower than if they are collected at the bud stage. Phosphorus is the exception to this rule, with concentrations expected to be 12%–16% at the bud stage, compared to roughly 8% at one-tenth bloom (Meyer et al., 2007).

Table 5. *Adequate Tissue Nutrient Concentrations for Alfalfa*

Nutrient	Levels are adequate when greater than:
Phosphorus (P)	0.20%
Potassium (K)	2.00%
Sulfur (S)	0.20%
Magnesium (Mg)	0.30%
Boron (B)	20 ppm
Manganese (Mn)	15 ppm
Iron (Fe)	40 ppm
Zinc (Zn)	12 ppm
Copper (Cu)	5 ppm
Molybdenum (Mo)	0.8 ppm

Notes. Concentrations are for whole plant samples (tops) collected at first bloom, which is approximately 1–2 days before the one-tenth bloom stage.

Source: Bryson et al., 2014

Dryland Alfalfa

The climate in most of Utah is not conducive to growing dryland alfalfa, but recommendations for the crop are shown below (Table 6). Recommended fertilizer rates for dryland alfalfa are much lower than for irrigated alfalfa because of the reduced yields and nutrient needs. Dryland alfalfa will typically yield half or a third as much as irrigated alfalfa. Potential returns should be evaluated critically to determine if fertilizer applications are economical.

Table 6. *Fertilizer Recommendations for Dryland Alfalfa*

Nutrient	Interpretations (ppm)		Recommendations (lbs/acre)
Phosphorus	Very low	< 4	50–70 P_2O_5
	Low A	≥ 4 to < 8	35–55 P_2O_5
	Low B	≥ 8 to 10	20–40 P_2O_5
	Marginal	≥ 10 to ≤ 12	0–30 P_2O_5
	Adequate/Normal	> 12 to < 30	--
	High	≥ 30 to < 60	--
	Very high	≥ 60	--
Potassium	Very low	≤ 50	180–220 K_2O
	Low A	> 50 to ≤ 70	140–180 K_2O
	Low B	> 70 to ≤ 100	80–120 K_2O
	Marginal	--	--
	Adequate/Normal	> 100 to < 250	--
	High	≥ 250 to < 400	--
	Very high	≥ 400	--
Sulfur	Low A	≤ 8	10–20 S
	Adequate/Normal	>8	--
Zinc	Very low	< 0.5	10 Zn
	Low A	≥ 0.5 to < 0.8	5 Zn
	Marginal	≥ 0.8 to ≤ 1	0–5 Zn
	Adequate/Normal	> 1 to < 50	--

Note. Soil analysis methods are the same as irrigated recommendations in Tables 2–4.

On-Farm Testing and Validation

These nutrient management guidelines were based on past and current research in Utah and in surrounding states and regions. This research is not comprehensive and does not represent every growing condition. These recommendations have been validated in recent on-farm trials at 12 farms. When fertilizer was required, the USU recommendations were predominantly the most profitable option when compared to other public and private laboratory recommendations. It is important to remember that these guidelines are constantly being refined and updated. They should be tested and validated on farms using best practices for on-farm testing and research (Yost et al., 2022).

Summary

Proper nutrient management is key to maintaining high yields, quality, and stand longevity for profitable alfalfa production. By the time that visible symptoms of nutrient deficiencies have appeared, yield, quality, and economic losses have already occurred. Soil tests provide a proactive opportunity to prepare fertilizer or amendment supplementation before the growing season. Fertilizer applications can greatly improve crop yield and quality and, in turn, greatly increase economic returns. Fertilizer is an important tool for crop production, but it is also important to consider environmental impacts of excess nutrient applications. In-season tissue testing can determine current nutrient levels, trends, and what fertilizer should be applied. These guidelines should be tested and validated on each farm but should provide a starting point for an adaptive nutrient management plan that maximizes return to fertilization.

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August 2024, Utah State University Extension
Peer-reviewed fact sheet

Suggested Citation: Baker, M., Yost, M., Anderson, C, Cardon, G., Gale, J., Creech, E., Zesiger, C., & Taylor, K. (2024). *Alfalfa nutrient management guide.* Utah State University Extension. https://doi.org/10.26077/f55a-e536