Fertilizing High Yielding Alfalfa in California and Arizona

By Nicholas Clark, Steve Orloff, and Mike Ottman

Some of the highest alfalfa yields in the world are grown in California and Arizona, with yields as high as 24 t hay/A reported. **Three distinct alfalfa-growing environments provide** examples of the nutrient management required to achieve high yields.

California (CA) and Arizona (AZ) are home to some of the world's highest yielding alfalfa fields. Average annual hay yields grown on the region's 1.1 to 1.2 million acres range from 5.5 to 9.0 tons/A. This represents 6% of the U.S. acreage and 10% of the production. Proper fertility management is key to producing high yield in these two states. Three particular alfalfa-producing regions will be discussed in this article: CA Intermountain, CA Central Valley, and the CA and AZ deserts.

While the environmental conditions and management practices differ greatly across these regions, there is common ground regarding methods for detecting and correcting nutrient deficiencies. The basis of this commonality is the alfalfa plant itself. Well-functioning alfalfa plants need the same proportion of nutrients to perform basic life functions and produce biomass no matter where grown.

The first thing to consider in nutrient management planning is the yield potential of each field. That number can be used to calculate potential nutrient removal and help guide fertilizer rate recommendations (**Tables 1** and **2**). Soil, plant tissue, and water analyses are the best way to determine the need for corrective action to resolve an alfalfa nutrient problem (**Tables 3** and **4**). Establishing benchmark soil and tissue testing areas (specific spots in the field where samples are collected year after year) helps to reveal trends in nutrient levels—either building or mining.

The macronutrients most limiting to CA and AZ alfalfa production are P, K, and S. Molybdenum and B deficiency may also occur in Intermountain CA.

Intermountain CA

Alfalfa is the number one irrigated crop in terms of acreage in the Intermountain area of northern CA. Production occurs in high-elevation valleys (2,500 ft. to 5,000 ft.) scattered throughout the region. Due to the latitude and the elevation, these valleys have a shorter growing season and cooler temperatures than the other production areas of California. Annual production is typically 4.5 to 8 tons/A (5 to 6.5 tons/A is most common) from 3 to 4 cuttings/yr. Alfalfa fertilization is more complicated in Intermountain area than in most other alfalfa production areas of CA for several reasons:

1. Because alfalfa is the dominant crop, most fields do not benefit from carryover nutrients from a preceding higher input crop like tomatoes, cotton, or melons.
2. A first cutting yield of 2 to 3 tons/A is commonplace and results in a relatively high nutrient demand.
3. Soil temperatures are low in spring, which affects nutrient availability at a critical growth period.
4. Many soils are inherently lower in fertility than in other regions.

Phosphorus is the most commonly deficient nutrient and

Table 1. Alfalfa nutrient removal during hay harvest.

Nutrient	Annual alfalfa yield, tons/A: 6	8	10	12	15
	Nutrient removal, lbs/A				
Nitrogen	360	480	600	720	900
Phosphorus (P_2O_5)	31 (71)	42 (95)	52 (119)	62 (143)	78 (179)
Potassium (K_2O)	240 (288)	320 (384)	400 (480)	480 (576)	600 (720)
Calcium	192	256	320	384	480
Magnesium	40	53	66	79	99
Sulfur	24	32	40	48	60
Iron	2.3	3	3.8	4.6	5.7
Manganese	1.5	2	2.5	3	3.8
Chloride	1.5	2	2.5	3	3.8
Boron	0.4	0.5	0.6	0.7	0.9
Zinc	0.3	0.4	0.5	0.6	0.75
Copper	0.12	0.16	0.2	0.24	0.3
Molybdenum	0.024	0.032	0.04	0.048	0.06

Adapted from Summers and Putnam (2008).

Table 2. Alfalfa fertilization recommendations.

Nutrient	Yield, tons/A	Soil or plant tissue test result: Deficient	Marginal	Adequate
		Fertilizer application rate, lbs/A		
Phosphorus (P_2O_5)	4	60-90	30-45	0-20
	8	120-180	60-90	0-45
	12	180-270	90-130	0-60
Potassium (K_2O)	4	100-200	50-100	0-50
	8	300-400	150-200	0-100
	12	400-600	200-300	0-150

Adapted from Summers and Putnam (2008); Orloff (1997).

Table 3. Reliability of alfalfa fertility testing method.

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

Adapted from Summers and Putnam (2008).

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulfur; B = boron; Cl = chloride; Cu = copper; Fe = iron; Mo = molybdenum; Mn = manganese; Zn = zinc.

Table 4. Interpretation of plant tissue and soil test results for alfalfa production.						
			Plant tissue concentration			
Nutrient	Plant Part	Unit	Deficient	Marginal	Adequate	High
Phosphorus (PO_4-P)	Middle third, stems	ppm	300-500	500-800	800-1500	> 1500
Potassium	Middle third, stems	%	0.40-0.65	0.65-0.80	0.80-1.50	> 1.50
Sulfur (SO_4-S)	Middle third, stems	ppm	0-400	400-800	800-1000	> 1000
Boron	Top third	ppm	< 15	15-20	20-40	> 200
Molybdenum	Top third	ppm	< 0.3	0.3-1.0	1.0-5.0	5.0-10.0
			Soil concentration			
Nutrient	Extractant	Unit	Deficient	Marginal	Adequate	High
Phosphorus	Bicarbonate	ppm	< 5	5-10	10-20	> 20
Potassium	Ammonium acetate	ppm	< 40	40-80	80-125	> 125
	Sulfuric acid	ppm	< 300	300-500	500-800	> 800
Boron	Saturated paste	ppm	< 0.1	0.1-0.2	0.2-0.4	> 0.4
Adapted from Summers and Putnam (2008).						

Alfalfa-producing regions of California and Arizona, USA.

is critical for high yield. Application of P fertilizer at least 60 to 90 days before the first cut produces maximum benefit. The greatest P response typically occurs on the first cut, because the yield is usually higher for this cutting, and nutrient availability is lower due to cool soil temperatures. Therefore, a fall or winter P application is more effective than mid-season applications.

Sulfur is the next most common nutrient deficiency. The source of S to use depends on soil S availability and the soil pH. If the field is very S deficient, a small particle size elemental S source is recommended for rapid oxidation to the sulfate form available for plant uptake. Gypsum is an alternative for low pH soil, because the S in gypsum is already in the sulfate form, and gypsum does not alter soil pH, whereas elemental S applications reduce pH. For moderately S deficient conditions, and pH neutral or alkaline fields, elemental S is the most cost-effective source. Two hundred to 300 lb S/A is an effective rate and should last for multiple years.

Potassium deficiency occurs in portions of the intermountain area. Deficiency symptoms are distinctive (spotting and yellowing along leaf margins).

Boron and Mo deficiencies are known to occur in Intermountain CA, particularly on low pH soils. There is a relatively narrow margin between deficiency and toxicity of some micronutrients (especially B), so it is important to apply the proper rate. A multiple-year supply can be applied. Often these nutrients are applied in liquid form and sprayed on during the dormant season.

Central Valley CA

Approximately 70% of CA alfalfa is produced in the Central Valley (CV), which is comprised of the Sacramento Valley (SV) in the north and San Joaquin Valley (SJV) in the south. Production spans from the San Joaquin/Sacramento Delta at sea level to the northern and southern valley boundaries at 500 ft. elevation. Soils range from high organic matter mucks near the Delta, to highly mineral alluviums from the enclosing mountain ranges and an ancient sea bed. A long growing season makes 7 to 9 cuts possible each year. Annual yields average 8 tons/A with some growers reporting up to 15 tons/A. Most varieties grown in this region have an Fall dormancy rating of 4 to 9 with more dormant varieties grown in the SV.

The most common nutrient deficiencies are P, K, and S. For regularly manured fields that are rotated with dairy forages, P deficiency is less common as P has a tendency to accumulate when crop N needs are met with dairy manure. However when soil tests are low, P fertilizer should be applied. When rotating into alfalfa, banded P fertilizer applications at planting increase P fertilizer efficiency. In established alfalfa fields, broadcast topdress applications of granular P fertilizer are usually made in late winter before the first cutting.

Although much less common than a P deficiency, K deficiency can also occur. It is most common on the sandier soils in the eastern SV and northern SJV. For most of the CV, K fertilizer is not needed. Fields that are regularly amended with dairy manure are unlikely to experience K deficiency and may have excess K, which can negatively impact feed quality of alfalfa.

Sulfur deficiency causes stunting and general yellowing, but may be difficult to identify by visual symptoms. Sulfur deficiency is more common in fields that receive irrigation water from snowmelt and where salinity tends to be low. Tissue testing is the only reliable way to determine an S deficiency. Further, if a S deficiency is suspected, tissue testing should occur in the late winter after the first cut when cooler soil temperatures tend to inhibit S oxidation to sulfate. If a S deficiency exists, this will be the time of year it is most likely apparent.

CA and AZ Deserts

The deserts of CA and AZ are characterized by a hot, dry climate and by soils that are alkaline (pH>7) and calcareous (containing free calcium carbonate, or lime). Phosphorus is the nutrient most often deficient in this region due to the high P-fixing capacity of these soils where soluble P is readily converted to insoluble mineral compounds. Phosphorus deficiency is most likely when the crop is growing during the cooler times of the year. Deficiencies of other nutrients such as K are also possible in this region, but are rare.

Splitting a P fertilizer application has not been shown to be an effective practice (**Figure 1**). Phosphorus fertilizer application timing is best when the crop is coming out of dormancy in the late winter or early spring, as P is more likely to be needed in the spring when temperatures are relatively cool. If an application is split, the amount of fertilizer applied at each application needs to be high enough to bring the soil test level P into the sufficient range.

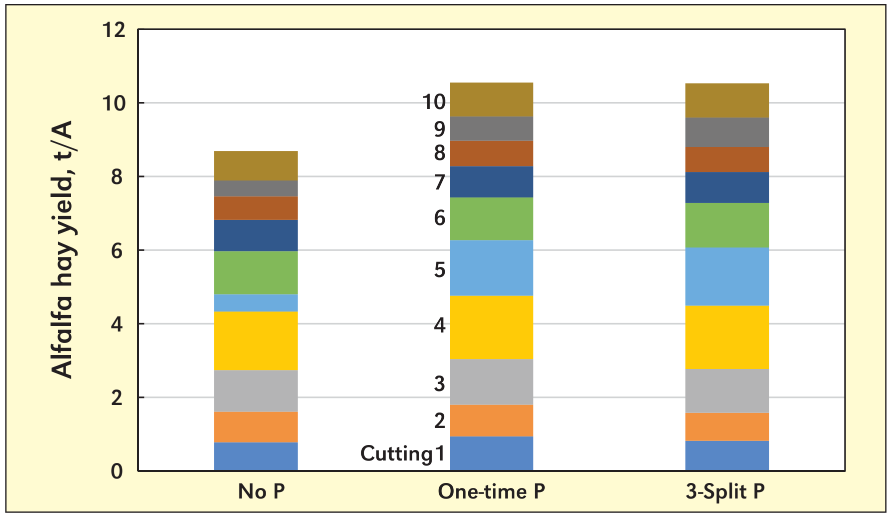

Figure 1. Alfalfa hay yield as affected by no P, a single application (117 lb P_2O_5/A), or three applications (39 lb P_2O_5/A) of MAP (monoammonium phosphate) over ten cuttings. Buckeye, AZ, 2015. Initial Olsen soil P concentration of 4 ppm (Ottman, unpublished).

The source of P fertilizer may affect alfalfa yield response in the deserts of CA and AZ. Phosphorus may be more available with acid-forming fertilizers such as phosphoric acid because less of the P may be rapidly fixed. Also, P held in organic form such as in manure is not subject to fixation by soil minerals such as what occurs with inorganic sources of P fertilizer. Granular MAP was found to be slightly more effective than water-run liquid ammonium polyphosphate (APP) for alfalfa nutrition (Ottman et al., 2006). MAP tended to move deeper into the soil, although the convenience of applying APP with the irrigation water should also be considered.

T. Roberts/IPNI

Potassium deficiency in alfalfa.

Potassium is usually at high concentrations in the desert soils of CA and AZ. However, K deficiency in alfalfa can occur on sandy soils and on soils with a history of crops that remove a large amount of K such as alfalfa and cotton. A deficiency is readily corrected with the application of granular K fertilizers.

N. Miles/IPNI Image

Boron deficiency in alfalfa.

TSI Image

Sulfur deficiency (right) vs. normal alfalfa plant (left).

Summary

The differences in soil fertility and climate that range from the northern border of CA to the desert valleys of AZ require different fertilization practices tailored to the needs of each region. However, plant nutrient requirements based on yield potential and testing programs to determine deficiencies remain constant. Knowing and using each field's yield potential as a guide for determining crop nutrient requirements is a universal tool. Soil and plant tissue testing for P and K and plant tissue testing for S, Mo, and B are the best ways to discover a nutrient deficiency and create a prescription for correction. These are the tried and true methods of maintaining high yielding alfalfa fields in this region. BC

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