NITROGEN, SULFUR, POTASSIUM AND PHOSPHORUS FERTILIZATION IN ALFALFA
WHEN ARE THEY NECESSARY?

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ABSTRACT

Determining when applications of nitrogen (N), sulfur (S), potassium (K) and phosphorus (P) fertilizer are needed is important to maintain alfalfa yield and quality. The Western U.S. is diverse in terms of climate, soil types, irrigation water need and availability, historical nutrient use and alfalfa production systems. Therefore, few generalizations hold regarding the timing and location of N, S, K and P deficiencies. Soil and tissue testing are the most reliable ways to assess alfalfa nutrient status and determine fertilizer needs. Soil test extractants and interpretations vary throughout the West. Growers must understand what soil test methods (mainly sampling depth and chemical extractants) are appropriate for their area and use interpretations (recommendation tables) developed for those methods. Tissue testing procedures and interpretations are more similar throughout the West, but growers must still match tissue sampling protocols (mainly growth stage and plant part) with the interpretation data. In this paper, summary information on critical soil and tissue test levels is presented, as well as recent alfalfa fertilizer response data from the Western U.S.

Key Words: alfalfa, nitrogen, sulfur, potassium, phosphorus, fertilization

INTRODUCTION

Alfalfa is the most common legume forage crop grown in the Western States. As recently as 1997, over 32 million tons of alfalfa was grown on approximately 7.4 million acres in the West (Morgan, 1997). In addition to its economic importance, alfalfa also fills an important rotational niche in Western agriculture. Being a deep rooted crop, alfalfa can scavenge nutrients remaining after the growth of less efficient, shallow rooted crops. Rotating out of alfalfa also provides a nitrogen source for following crops as the root system decomposes.

Due to the economic and agronomic importance of alfalfa in the West, a considerable amount of inorganic fertilizer is applied to this crop. Determining when applications of nitrogen (N), sulfur (S), potassium (K) and phosphorus (P) are needed is important to insure adequate alfalfa yield and quality. Over-generalizations made about the occurrence of N, S, K and P deficiencies are dangerous. Western U.S. climates, soil types, historical nutrient use patterns and alfalfa production systems are highly variable and directly impact the need for N, S, K and P. Therefore, some form of soil and tissue testing program must be used to identify deficiencies and monitor the nutrient status of alfalfa over time.

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The purpose of this paper is to briefly describe situations where N, S, K and P deficiencies *may* occur, the visual appearance of these deficiencies, and critical soil and tissue test levels for defining deficiencies and determining fertilizer application rates. Some data from recent alfalfa fertility trials is presented to illustrate the importance of monitoring the nutrient status of alfalfa and making fertilizer applications when necessary.

RESULTS AND DISCUSSION

Nitrogen (N). Alfalfa is a legume and through a symbiotic relationship with bacteria obtains N required for growth from the atmosphere. Most references acknowledge that, during establishment and before bacterial symbiosis develops, a small amount of N is beneficial (Mortvedt et al., 1996; Koenig et al., 2001). This recommendation is applied when soil N prior to planting is below critical levels (Table 1). Applications of larger amounts of N during establishment are thought to inhibit bacterial colonization of the root system and may reduce the growth of mature alfalfa plants.

Table 1. Summary of basic N fertility data and recommendations for alfalfa.[1]

Data	**Value or recommendation**
Nitrogen removal by alfalfa	approximately 60 lb N per ton of hay
Critical tissue concentration	3 to 4% N (whole tops, 1/10 bloom) 4 to 5% N (top 1/3 of plant, 1/10 bloom)
Visual deficiency symptoms	Light green, stunted plants, low protein
Situations where deficiency may be observed	cold soils, uninoculated or ineffective inoculation, low pH, stress
Critical soil test value for new stands at establishment	Less than 15 ppm NO_3 or Less than 3 or 4 ppm NO_3-N
Fertilizer recommendation for new stands	20 to 40 lb N/acre
Fertilizer recommendation for established stands	generally not recommended

[1]Data taken from the Western Fertilizer Handbook (California Plant Health Association, 2002) and various state extension publications referenced at the end of this paper.

Nitrogen application in established alfalfa stands is still controversial. An excellent review of N fertilization of alfalfa was published by researchers at Oregon State University (Hannaway and Shuler, 1993). In this review, the authors reported on dozens of studies evaluating alfalfa yield and protein responses to N fertilization. Few of the studies found any positive effects of N fertilization on established alfalfa; however, enough studies have shown a yield and/or protein response to N fertilization to warrant consideration. Situations in which alfalfa may respond to N fertilization appear to include poor or ineffective nodulation due to use of the wrong, old or damaged inoculant, and stresses that can reduce nodulation or bacterial activity. Stresses can include low soil pH (acid soils), extreme hot or cold soil temperatures, and drought or salinity

stress. If producers suspect low rates of N fixation in alfalfa stands they should first try to identify the cause and then consider on farm testing to determine whether fields will respond to N fertilization.

Sulfur (S). Sulfur is an important component of several amino acids and has been shown to influence the yield, protein content, stand density and stand life of alfalfa. Yield responses of up to 300% have been reported under severe S deficiency conditions; however, more typical yield responses to S fertilization are in the range of 15% to 25%. Early research (Westermann, 1974, 1975) established critical tissue S and soil sulfate-S (SO_4-S) concentrations for alfalfa grown in the Western U.S. (Table 1). More recent recommendations are based on soil test results (Koenig et al., 2001) or an annual need established by local research (Gardner et al., 2000).

Table 2. Summary of basic S fertility data and recommendations for alfalfa.[1]

Data	**Value or recommendation**
Sulfur removal by alfalfa	5 lb S per ton of hay
Critical tissue concentration	0.20 to 0.25% S (whole tops, 1/10 bloom) 0.25 to 0.30% (top 1/3 of plant, 1/10 bloom)
Visual deficiency symptoms	Light green color, stunted plants, thin stems, low protein content
Situations where deficiency may be observed	sandy, low organic matter soils, high elevation and/or high rainfall locations
Critical soil test value	Less than 25 ppm SO_4 or Less than 8 ppm SO_4-S
Fertilizer recommendation	20 to 40 lb S/acre

[1]Data taken from the Western Fertilizer Handbook (California Plant Health Association, 2002) and various state extension publications referenced at the end of this paper.

Many high elevation areas have been found to be low in S. High precipitation coupled with low irrigation water S concentrations and a history of high yielding alfalfa production explain the occurrence of these deficiencies. A recent comparison of sulfur sources and rates at two locations in Utah showed responses on the order of 16 to 20% above an unfertilized control with various sources of sulfur (Figure 1). Initial soil test SO_4-S ranged from 3.0 to 3.5 ppm. Sulfur sources included ammonium sulfate (AMS), potassium-magnesium sulfate (K-MAG), potassium sulfate (SOP), potassium polysulfide (K-Sul) and ammonium polysulfide (N-Sul).

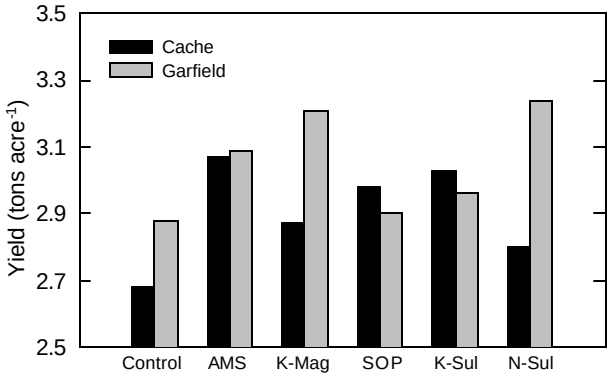

Figure 1. Effect of S source on alfalfa yield in 2001 (Koenig, unpublished data).

Potassium (K). More K is removed than any other nutrient except N by alfalfa (Table 3). Potassium deficiency, however, is a relatively recent occurrence in the West. In the mid-1950s, fertilizer guides from Utah State University declared that no K deficiencies existed due to the high native levels of K in Utah soils and high K concentrations in many irrigation waters (Nielson *et al.*, 1955). Fertilizer guides from other Western States contain similar statements. A long history of high-yielding alfalfa production has depleted native soil K levels to the extent that most Western States now encourage testing for K and make K fertilizer recommendations.

Table 3. Summary of basic K fertility data and recommendations for alfalfa.[1]

Data	**Value or recommendation**	
Potassium removal by alfalfa	60 lb K_2O per ton of hay or 50 lb K per tons of hay	
Critical tissue concentration	2.0% (whole tops, 1/10 bloom) 2.5 to 3.5% (top 1/3 of plant, 1/10 bloom)	
Visual deficiency symptoms	thin stands, leaf margin necrosis (dead spots on outer edges of leaves), low stress tolerance	
Situations where deficiency may be observed	sandy soils, high elevations, sites with a long history of alfalfa production	
Critical soil test value ("Olsen" or sodium bicarbonate extract method)	Less than 150 ppm K	
Fertilizer recommendations	Soil test level (ppm)	lb K_2O per acre
	0 to 40	300
	40 to 70	250
	70 to 100	150
	100 to 150	100
	above 150	0

[1]Data taken from the Western Fertilizer Handbook (California Plant Health Association, 2002) and various state extension publications referenced at the end of this paper.

Soil test extractants for K include sodium bicarbonate ("Olsen" extract), ammonium bicarbonate and ammonium acetate. Soil test procedures for K, like P, are reliable indicators of deficiencies and fertilizer requirements. Recent research from Utah State University showed alfalfa yield responses to relatively high K application rates on low K-testing soils (Figure 2). Due to the high K requirements of alfalfa, frequent and relatively high rates of K fertilizer will be required to maintain high yields once native soil levels are depleted.

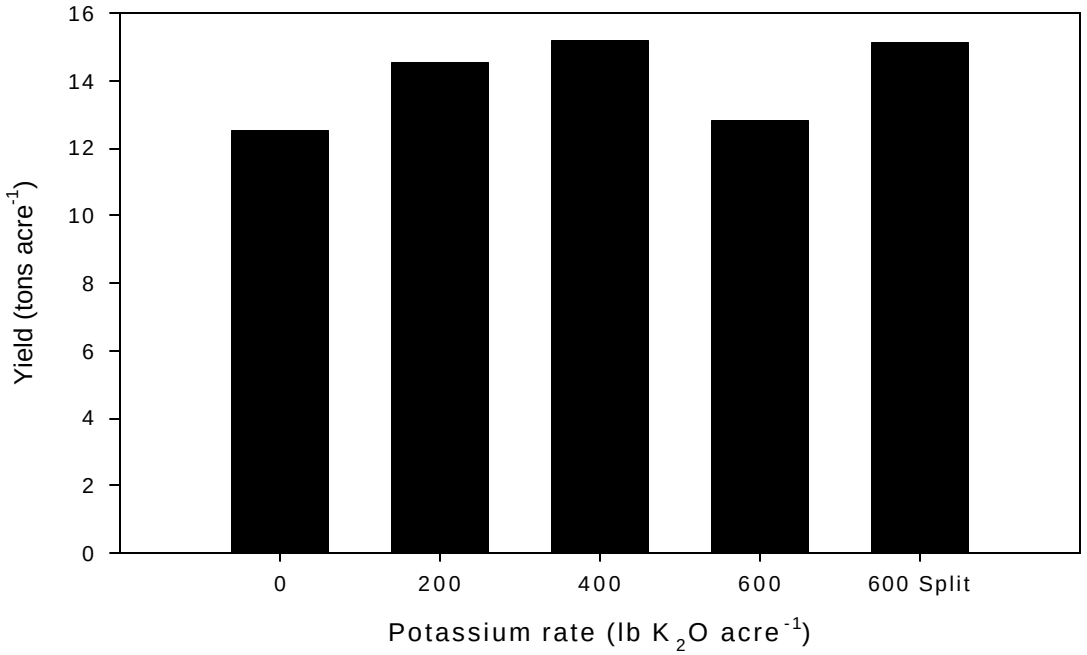

Figure 2. The effect of K rate on alfalfa yield at a Utah State University Research Farm. Data are from 1999. The 600 split application consisted of 200 lb K_2O per acre applied in April, and 200 lb K_2O per acre applied after the first and second cuttings. Initial soil test K was 73 ppm. Data are from Koenig et al. (2002).

Phosphorus (P). Phosphorus is essential for alfalfa production and likely represents the most common fertilizer input for this crop across the Western U.S. Phosphorus recommendations in Western States with alkaline-calcareous soils are based on a sodium bicarbonate ($NaHCO_3$) extractant or "Olsen" test (Table 4). Correlations between soil test P and alfalfa yield are normally very good for the Olsen P test (Figure 3). These relationships are used to identify the critical soil test P above which fertilizer recommendations are not made (Table 4).

Fertilizer guides from most Western State recommend that P be applied and incorporated before establishing an alfalfa crop. Since P is relatively immobile, placement below the soil surface improves root access and prevents P from being stranded on the surface of dry soil. When P needs are identified for established alfalfa, application as soon as possible is recommended.

Various P fertilizer sources are available in the Western U.S. Research has generally found that conventional dry (11-52-0, 0-45-0) and liquid (10-34-0, phosphoric acid) fertilizer sources are equally effective for alfalfa (Figure 4). Selection of a P fertilizer source should be based on availability and cost per pound of P_2O_5.

Table 4. Summary of basic P fertility data and recommendations for alfalfa.[1]

Data	**Value or recommendation**	
Phosphorus removal by alfalfa	15 lb P_2O_5 per ton of hay or 6.5 lb P per ton of hay	
Critical tissue concentration	0.20 to 0.25% (whole tops, 1/10 bloom) 0.25 to 0.35% (top 1/3 of plant, 1/10 bloom)	
Visual deficiency symptoms	Dark green or blueish color, stunted plants, thin stems, weedy stands	
Situations where deficiency may be observed	anywhere inorganic fertilizer or manure has not been applied recently	
Critical soil test value ("Olsen" or sodium bicarbonate extract method)	Less than 15 ppm P	
Fertilizer recommendations	Soil test level (ppm)	lb P_2O_5 per acre
	0 to 3	200 to 250
	4 to 7	150 to 200
	8 to 10	100 to 150
	11 to 15	50 to 100
	above 15	0

[1]Data taken from the Western Fertilizer Handbook (California Plant Health Association, 2002) and various state extension publications referenced at the end of this paper.

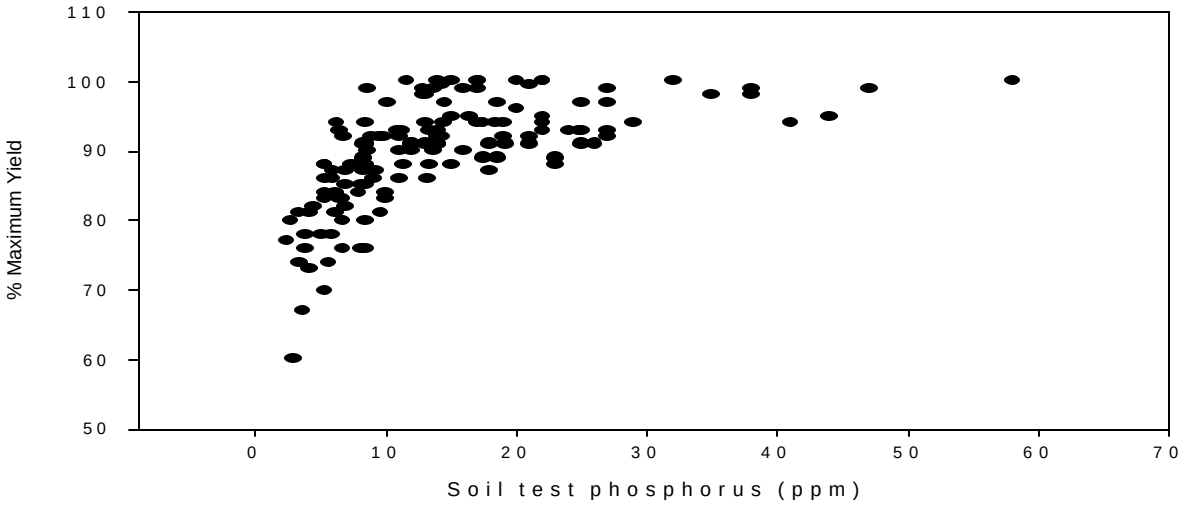

Figure 3. Relationship between soil test phosphorus (Olsen method) and percent maximum alfalfa yield. Data are from 3 sites over 2 years (Koenig et al., 1999).

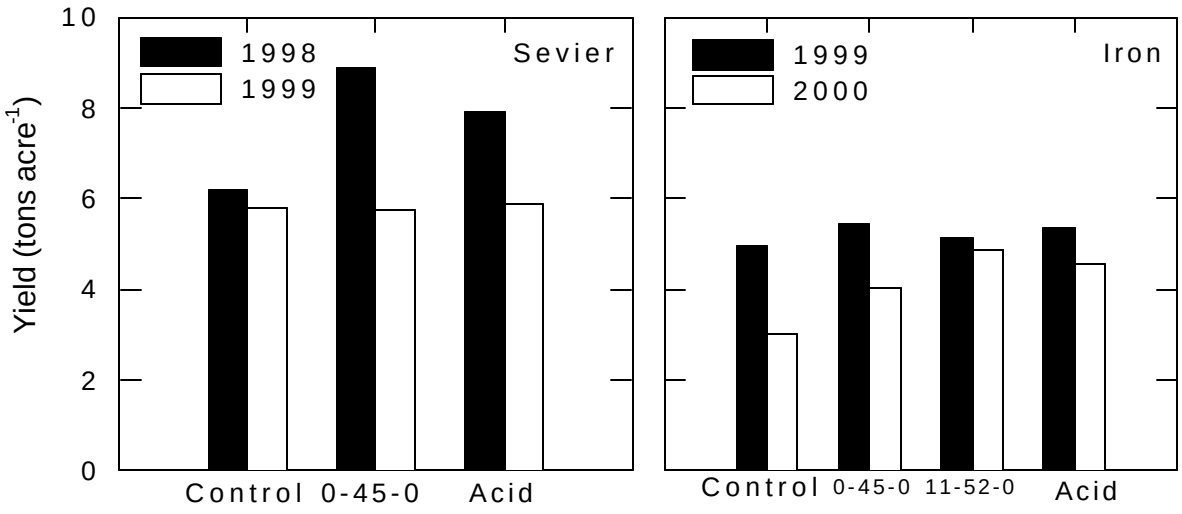

Figure 4. The effect of P fertilizer source on alfalfa yield at 2 locations. Phosphorus was applied at a rate of 150 or 230 lb P_2O_5 per acre for each source. Data from Reid et al. (*in press*).

ON FARM TESTING AND RECORD KEEPING

The role and importance of on farm testing and record keeping cannot be overstated when developing an alfalfa fertility program. Different soils respond differently to fertilization in terms of the initial and long-term impacts on soil test levels and crop response. Also, different yield levels will require different amounts of fertilizer inputs over time. The soil and tissue test information presented in this paper should be viewed as a guideline to be refined for specific soil types and alfalfa production systems.

On-farm testing is one way in which alfalfa growers can refine fertility programs for specific situations. An on farm test might involve a trial to determine whether alfalfa responds to Non the farm, or whether a higher rate of P or K results in higher yields. When conducting an on farm test, treat several strips in a field with the new fertility practice and alternate strips with the standard practice. Where possible, treat several test strips in a field and only change one variable (such as nutrient type or rate) for each trial. Keep individual records of fertilizer applications, soil and tissue test values, and alfalfa yield for the trial to assess whether the new practice improved yield or changed soil test values.

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