Spectrum Analytic Inc.

FERTILIZING ALFALFA

Soil Analysis
Plant Analysis
Fertilizer Analysis
Manure Analysis

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Introduction

Alfalfa can produce exceptionally high yields when given the right conditions. Some examples of high, non-irrigated alfalfa yields are seen in the following tables.

Non-Irrigated Year	Location	Yield (T/acre)
1981-82 (2 Yr. avg.)	Michigan State Univ	10.0
1982	Michigan State Univ.	10.8
1985	Univ. of Wisconsin	11.5
1987	Univ. of Maryland	11.3
1987	Delaware State College	12.0

Irrigation and long growing seasons increase the yield potential. In the 1981-82 growing season, researchers at the University of Arizona, Yuma Valley Agricultural Center produced the current world-record alfalfa yield with 24.1 tons/acre. Before you get too excited about growing 20 T/ac of alfalfa, you should know that the Arizona yield occurred where they had a 12 month growing season and they were able to take 10 cuttings during the year. Even with the advantage of irrigation and a year-long growing season, this was excellent alfalfa, as evidenced by the 2.41 ton/cutting average. In a 4-cut/yr Midwestern program the Arizona yield roughly equals a yield of 9.64 T/ac. While not everyone can produce yields like these, they demonstrate the tremendous yield potential of alfalfa.

To better appreciate these high yields, they can be compared to the average yields in other states. As you can see, the state average yields are well below what is possible. Incomplete data for later years suggests that average yields across the country have not changed significantly from those presented here in more recent years. However, years like 2004 with better rainfall show higher average yields.

Alfalfa Statistics 2001, 2002								
	Yield (T/ac)			Yield (T/ac)			Yield (T/ac)	
State	2000	2001	State	2000	2001	State	2000	2001
AZ	8.3	8.0	MA	2.3	2.3	OK	3.3	2.6
AR	2.5	3.1	MI	3.7	3.6	OR	4.2	4.3
CA	7.0	7.2	MN	3.6	3.5	PA	3.1	2.5
CO	3.7	3.8	MO	3.1	3.1	RI	2.5	2.2
CT	2.2	2.3	MT	2.1	2.1	SD	2.1	2.2
DE	5.0	3.4	NE	3.1	3.6	TN	3.7	3.9
ID	4.2	3.9	NV	4.6	4.5	TX	4.0	4.9
IL	3.8	3.9	NH	2.0	2.0	UT	4.0	4.0
IN	4.1	4.0	NJ	3.0	3.4	VT	2.0	2.0
IA	3.9	3.7	NM	5.2	5.0	VA	4.0	3.1
KS	4.1	4.6	NY	2.4	2.8	WA	5.0	4.8
KY	3.9	3.7	NC	2.7	3.0	WV	3.2	2.5
ME	2.2	2.2	ND	2.4	2.1	WI	3.0	2.5
MD	4.4	3.1	OH	4.0	3.5	WY	2.3	2.2

Some will ask if higher yields are actually profitable. Each grower will have to do his own math, but most calculations show that the cost of inputs for a higher, but attainable yield is an excellent investment.

If only the fertilizer program is changed, you are not as likely to achieve higher yields. Higher yields are typically the result of a coordinated production program where different inputs and management practices compliment each other. Most authorities recommend the following practices in addition to proper lime and fertilizer programs.

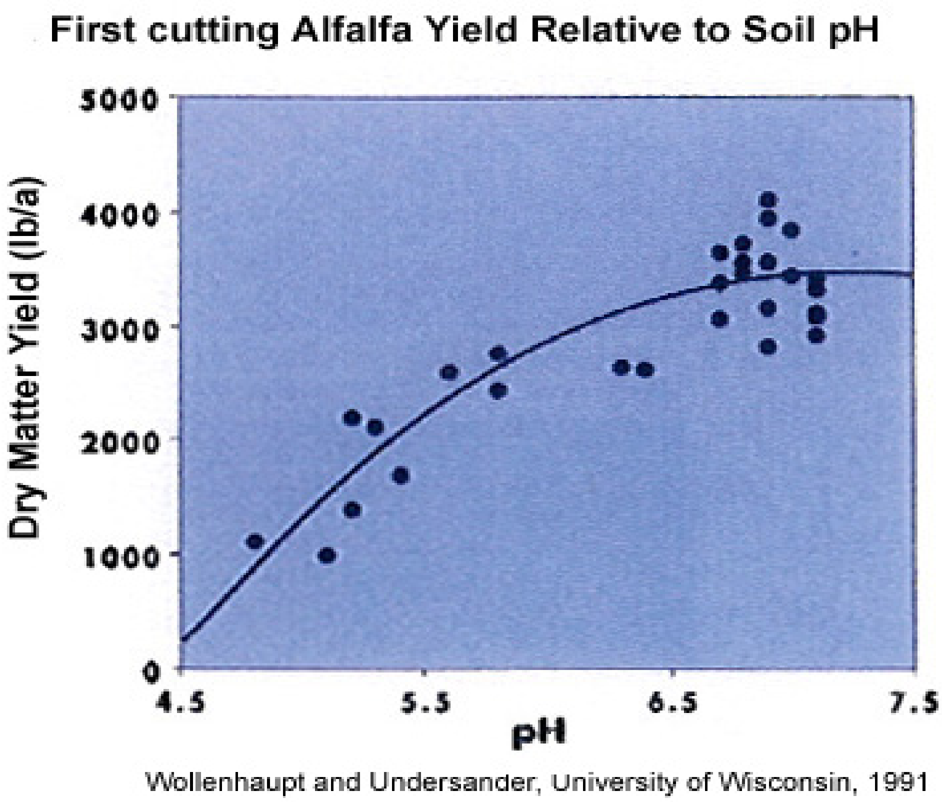
- Select well drained land
- Take soil samples to determine the fertilizer program
- Use certified, inoculated seed of an adapted variety (with proven high yield potential)
- Band seed with press wheel and starter fertilizer at the appropriate rate, date, and depth
- Apply proper fertilizer rates (replacement plus buildup) in annual split applications
- Reduce competition: control weeds and do not plant a companion crop
- Control insects, especially potato leaf hopper
- Harvest on time

In the following pages we will focus on alfalfa fertility. At the end of the paper there is a short discussion on several of the other aspects of alfalfa production.

You will find many pictures of visual nutrient deficiency symptoms in the following pages. Please understand that visual nutrient deficiency symptoms are a sign of severe problems. You should never see nutrient deficiencies in any crop! ***You cannot expect high yields when a crop goes through a period of starvation!*** This is why plant analysis is so important. **Plant analysis is the only way to identify nutrient stress before visual "starvation" symptoms appear.**

Soil pH

The first goal of any alfalfa fertility plan is to get the soil pH into the correct range. While some authorities suggest that alfalfa soil needs a pH around 6.5 and some respectable yields can occur at this pH, most high alfalfa yields occur at soil pH's around 7.0. Maintaining a soil pH at, or slightly above 7.0 can cause micronutrient shortages in some soils. Therefore, it is important to counter this with appropriate fertilizer programs. See the section on micronutrients for suggestions.



Nitrogen (N)

Alfalfa utilizes about 56 lb of N/ton of yield. Do your own arithmetic and you will see that any high yield requires large amounts of N. Luckily; alfalfa is very efficient at N fixation. In nearly all typical farming situations, nitrogen will not be needed for alfalfa after it is established. Spectrum Analytic recommendations suggest that 20-30 lb. N/acre be applied at seeding, (crop codes 10 and 134 for fall seeding and spring seeding respectively) and none thereafter. This is consistent with a number of Universities. However, for alfalfa to produce the large amount of needed N, it requires adequate amounts of other nutrients.

Over the years, a number of research projects have looked at applying N to established alfalfa. The theory apparently being that legumes must have an upper limit for N production, and N might limit yields at some point. Given that alfalfa contains about 56 lb. N/ton and there have been yields of 10 to 12 T/acre yields produced without added N, alfalfa appears capable of producing the approximate 550-670 lb. N/acre needed for those yields. The majority of research results into adding supplemental N to established alfalfa found that the extra N provided no benefit to yield or quality. In some cases, yield and/or quality was reduced by additional N.

However, some record yields have received high rates of N. For example, the 24.1 T/acre of irrigated alfalfa grown in Arizona received 508 lb. N/acre that same study produced 19.4 T/acre with 183 lb. N/acre. Various other N rates produced roughly proportional yields. Without going into much detail on that study, their response to N was not linear, but appeared to be an interaction between N and irrigation practices. Occasional other research gained a benefit from more modest rates of N, but these results were a distinct minority. So what should a grower do about N? Probably not apply any N after seeding. However, if... 1) the field is a test area or yield contest area, 2) all other inputs are optimized, and 3) you want to see what happens, you might try 100 to 200 lb. N/acre. There is no proven best timing for N application, but logic would suggest N be applied after the plants have nodulated and before the strongest growth periods in regrowth years.

General Phosphorous and Potassium

Fertilizing alfalfa and other crops with P, K, and some other nutrients is as much about building soil tests as it is about the needs of the crop. As with most crops, high alfalfa yields are more dependent on a strong soil test than on high fertilizer rates in any single season. This may sound redundant, but it is based on the fact that low testing soils have a large capacity to convert or “fix” applied nutrients into less available forms. Therefore, the grower must satisfy his soils fixation capacity before he can expect much higher yields. This nutrient fixation is simply another term for soil buildup. Of course, soil buildup is a slow, costly process. However, strong soil tests are one of the keys to sustained high yields of alfalfa. If growers plan to produce high yields, while maintaining or increasing the soil test, they must both replace the nutrients needed by the crop, plus add additional nutrients to increase the soil test.

When we talk about alfalfa nutrients and soil tests, we are primarily interested in P and K. Alfalfa needs all of the same 13 essential nutrients as every other plant, but it puts a very heavy demand on P and K. We can also build up the soil levels of many, but not all other nutrients. Those that are not practical to build up include N, S, B, Fe, Mn, and Mo. While there can be some variability in removal values for N, P_2O_5, and K_2O, the following data are generally accepted as being reasonable.

Major Nutrient Removal by Alfalfa

	N	P_2O_5	K_2O
lb. /ton	56	12-15	55-70
lb. /10 ton	560	120-150	550-700

As you can see, alfalfa removes a large amount of P_20_5 and K_2O. While a high testing soil will supply part of this need, a low testing soil may fix much of the applied nutrients, thus requiring much more than crop removal.

Having listed the very high P and K demands of alfalfa, some readers will have read research or other reports of high yields achieved on lesser soil test levels or fertilizer rates. This can happen when other conditions are exceptional. For example, good alfalfa has a very deep root system that enables it to benefit from higher than average subsoil fertility and moisture. Of course, if subsoil fertility or other conditions are unfavorable, it can hurt yields. Like most crops, if there are physical barriers to root penetration to deeper soil depths it will normally restrict yields. Ideal rainfall will also permit higher yields than a soil test and fertility program would otherwise suggest. Most nutrients are taken up by plants as they absorb soil water. When water is limiting, less nutrients are taken up. Also, plants under water stress simply grow more slowly, thus limiting yield. While it has been shown many times with many crops that well-fed crops withstand moisture stress better than “hungry” ones, water stress still hurts nutrient uptake and yields.

Top alfalfa is rarely produced with a single fertilizer application per year. Fertilizer should be split-applied at least two times, usually after the first and third cuttings. More applications may be beneficial in some situations. Late winter and early spring applications are not recommended because of the damage that can be done to plant crowns.

Overcoming soil fixation of P and K (soil buildup) is perhaps the most difficult and expensive part of improving alfalfa yields. Unfortunately, there isn’t an alternative to good soil tests nor a simple formula to calculate the amount of nutrient needed to build a soil test (P or K), because all soils are different. Researchers have shown that the amount of P or K needed to build up the soil is less efficient when the beginning soil test is lower. In other words, it takes more applied nutrient to increase the soil test 1 lb/ac (or ppm) on lower beginning soil test levels than it does on higher ones. Data listed under the individual nutrients will illustrate this point.

Phosphorous (P)

Phosphorus is one of the “building-block” nutrients. It has two main functions in all plants.

Function

- Structural part of DNA and nucleic acids in the cell nucleus
- Principle nutrient in the production of energy within the plant

If these two functions don’t seem to agree with others that you have seen, it’s because these are primary functions, and most lists contain the results of these functions. Some examples of processes that require a lot of energy include

- Faster growth and earlier maturity
- Flowering
- Seed production
- Root growth

Simple growth can be a high-energy process when environmental or soil conditions are poor. All of this is part of the reason that we see significant response to P in cold-wet soils. And of course, you can’t build plant cells without DNA or nucleic acids, so that function is obvious.

Getting Adequate P into Alfalfa

A plants ability to take up enough P is influenced by several general factors

- An adequate amount of P in the soil
- Few interactions that limit P availability
- A healthy, expansive, and vigorous root system

Factors Affecting P Availability

Several soil and plant factors affect the plants availability other than the amount of P in the soil. Some are related to the fact that P is very immobile in the soil. They include...

- **Soil pH:** A soil pH above pH 7.2 or below about 6.5 reduces the amount of P that is available to alfalfa.
- **Soil Temperature:** Cold soil greatly reduces the amount of P uptake by most plants
- **Soil Compaction:** Roots draw P from a cylinder of soil around each root that is about 1/10” wide. Soil that is farther from the root than this will not provide much P to the plant. This small amount of soil can be quickly depleted, so the roots must constantly grow into new soil to obtain adequate P. Compacted soil can physically restrict the amount of root growth, thus restrict the amount of P that the plants can obtain from the soil.
- **Soil Oxygen:** Alfalfa roots must have adequate oxygen in the soil “atmosphere” to properly absorb P, as well as perform many other functions. Soil that tends to stay wet reduces the amount of oxygen in the soil atmosphere. Compacted soils tend to have less oxygen due to the smaller volume of pores (empty spaces) in the soil.
- **Root Health and Vigor:** Anything that reduces the efficient function of roots, such as disease or pest damage will reduce the uptake of P, as well as other nutrients and water.

- **Ca-P:** Although not proven with alfalfa, work with some plants has shown that increasing the Ca content of the roots has increased P uptake. This is not as likely to be effective with alfalfa, due to the higher soil pH, thus higher soil Ca content of the crop.
- **P-Zn, Cu, Fe, Mn:** Most of us have been told that high levels of soil P will reduce the uptake of Zn, Cu, Fe, and sometimes Mn. The reverse is also true. It is generally believed that high levels of available P in the soil results in the precipitation of compounds containing P and the micronutrient on the root surface. It is very unlikely that most growers will have a soil where excessive amounts of these micronutrients could reduce P availability. However, with the increasing applications of municipal sludge, an excess of some micronutrients or other elements that might react with P would seem to be a possibility.

We have previously discussed the amount of P that alfalfa removes from the soil for each ton of yield. That is the minimum P requirement, unless the soil test is higher than needed. Many soils have weak P levels. These soils have the ability to tie-up or “fix” some or most of the fertilizer P that is applied. In these situations, the fertilizer program must both supply an adequate amount of P to support the expected removal, plus an additional amount to overcome soil fixation. Said more simply, the grower really doesn’t have a choice between maintenance and buildup programs when planning for higher yields. The soil effectively tries to build up the P level, through fixation, whether we like it or not.

Most agronomists say that it takes about 9-10 lb. of applied P_2O_5/acre (in excess of the crop requirement) to increase a soil test 1 lb. P/acre (1 lb/acre is equivalent to 2 ppm). Research by William Thom and James Dollarhide at the University of Kentucky supports this rule-of-thumb, but also indicates the effect of the beginning soil P test on the buildup efficiency. The following data is based on a regression equation developed from their research.

Soil P Buildup Efficiency

Initial Soil P	lb P_2O_5 per lb Soil P Increase	Initial Soil P	lb P_2O_5 per lb Soil P Increase
5	30.1	65	5.1
10	18.7	70	4.9
15	14.1	75	4.7
20	11.6	80	4.5
25	9.9	85	4.3
30	8.8	90	4.1
35	7.9	95	4.0
40	7.2	100	3.8
45	6.6	105	3.7
50	6.2	110	3.6
55	5.8	115	3.5
60	5.4	120	3.4
Adapted from Thom & Dollarhide, U of KY, 2002			

While this data may be applicable to a large number of soils and conditions, individual situations may be quite different. For example, one soil type in this research required as much as 57 lb additional P_2O_5 per 1 lb of soil P. In two other soils it required between 15 and 20 lb P_2O_5 per 1 lb soil P with the starting soil P between 30 and 50 lb/acre, rather than the 6 to 9 lb P_2O_5 shown in this table.

Soil test reduction works in a similar manner, but in reverse. Wells and Dollarhide grew alfalfa without fertilizer on 16 different soils for two years and measured the soil P drawdown. The average P_2O_5 removal across the 16 soils was 150 lb/ac and the average soil test reduction was 19 lb P/ac, for a drawdown ratio of about 1 lb soil P per 8 lb P_2O_5 removed. This is a ratio similar to that required to build up many soils. However, the differences in draw down ratios among the 16 soils was large, ranging from a low of 3.2 lb P_2O_5 removed per 1 lb soil P reduction to a high of 37.8 lb P_2O_5 removed per 1 lb. soil P reduction. From the data reported, there was no relationship to initial soil test P level, so we assume that other unreported factors were involved in causing this wide difference in soil test change.

At Spectrum, we vary our soil test P status a little by CEC (higher CEC's need less P to be Good); however, the general "Good" range for most soils is between 60 and 100 lb/ac (30-50 ppm). Phosphorus is not a cation like K, so it doesn't react to CEC in the same way. However, some early work and our experience since then indicates that lower CEC soils seem to benefit from higher P soil tests than higher CEC soils. Given this and the KY data, if you have a 40 lb P/ac test and want to raise the soil P test to 80 lb/ac while producing 10 t/ac of alfalfa, it will likely require the following P_2O_5 program.

Soil test target of 80, minus present test of 40 =	40 lb P soil test deficit
P Removal of 10 T/ac alfalfa =	120 to 150 lb. P_2O_5/ac
5 Yr Buildup = (40 × 7.3) ÷ 5 =	58 lb. P_2O_5/ac
Total annual rate of P_2O_5/ac =	**178 to 208 P_2O_5/ac for a 5 year buildup program**

Many farmers will be unable or unwilling to apply this rate of P_2O_5, but **crop physiology and soil chemistry are not affected by economics or opinions.** These processes simply obey the laws of chemistry and biology, regardless of economics. Therefore, the grower must decide if he is willing or able to make the investments necessary to produce higher yields while improving his soil test levels. If he produces the higher yields, the larger investments are typically justified. Keep in mind that where a grower has a low soil test, it is probably not appropriate to set a high yield goal. Normally, higher yields come after the soil test has been increased to the Good range, not before. Growers with weaker soil tests must be willing and able to over-fertilize the land in the early years, in order to achieve higher yield goals possible in later years.

The following table lists Spectrum's soil P status table and P_2O_5 recommendations for various soil P status levels and alfalfa crop situations. The numbers listed in the Soil Status Table are the top of each soil test P range. The P_2O_5 recommendations in the two recommendation tables occur in the center of each status range. The recommendations for crop 10, Alfalfa-Fall Seeding is not adjusted for yield goal since it is only intended to establish the crop and we assume that no cutting will be taken.

Soil Status Table

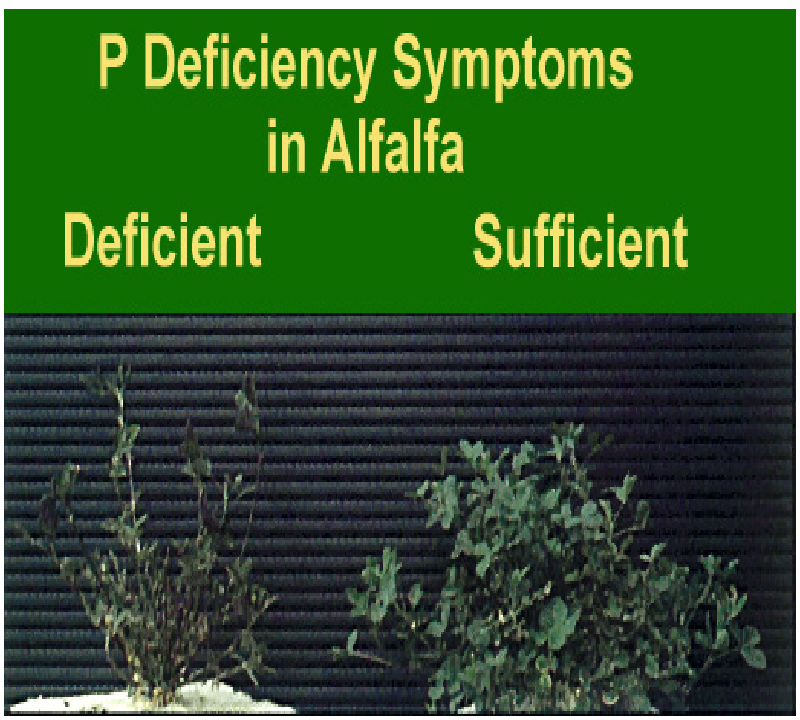
CEC	0.1	5	10	15	20	25	30	35+
Phosphorous (lb./acre): soil target pH >6.0								
Low	50	40	34	30	27	24	23	20
Medium	100	80	69	62	55	49	43	40
Good	150	120	109	99	93	88	84	80
High	275	220	202	186	177	171	167	160
V High	276+	221+	203+	187+	178+	171+	168+	161+

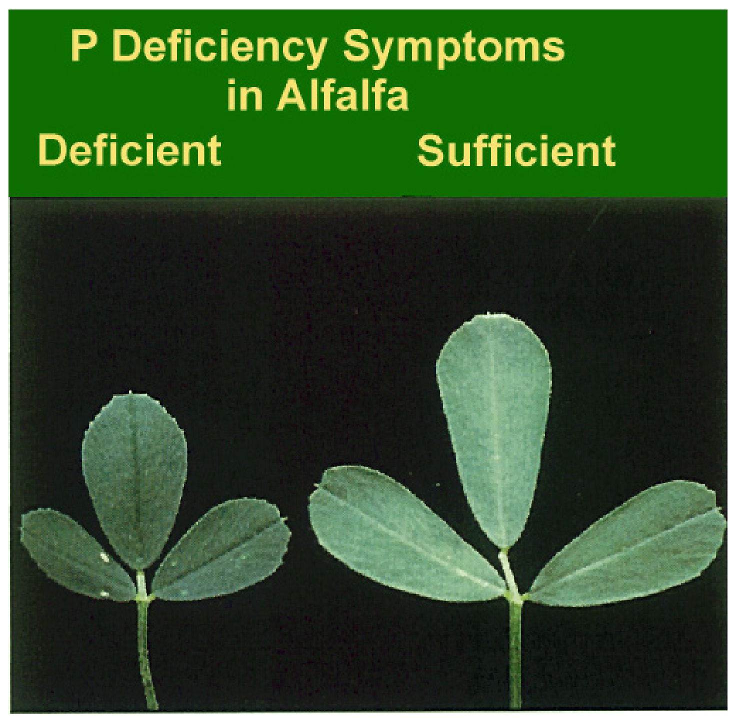
Alfalfa Topdress, Crop 11						
Soil Applied P_2O_5 Recommendations						
	Yield Goal (T/acre)					
	3	5	7	9	11	13
Soil P Status	lb P_2O_5/acre					
Low	153	177	222	252	282	312
Med	99	123	168	198	228	258
Good	36	75	105	135	165	195
High	0	0	0	0	0	0
V High	0	0	0	0	0	0

Alfalfa-Fall Seeding, Crop 10	
Soil Applied P_2O_5 Recommendations	
	All Yield Goals
Soil P Status	lb P_2O_5/acre
Low	156
Med	102
Good	30
High	0
V High	0

Note: Spring seeded alfalfa is crop number 134 and the P_2O_5 recommendations are the same as crop 11-Alfalfa Topdress

Visual Symptoms of P deficiency in alfalfa may include reduced plant height and smaller leaves, and/or dark green or purplish leaves, with tip death in some cases. Upward tilting of leaflets and stunted growth may occur. Reduced nodulation and increased winter kill may be other consequences. Alfalfa plants deficient in P may appear water stressed.





Potassium (K)

Potassium is not a building-block of any plant part, but it probably has the greatest effect of all nutrients.

Functions

- Critical for photosynthesis
- Critical for the production, storage, and transfer of plant foods made in the leaves, to other parts of the plant
- Critical for N fixation by legumes
- Critical for water-use efficiency
- Critical for the production of plant protein

Factors Affecting K Availability

- **Soil Test Level (Amount and Percent Saturation):** Within certain limits, soils with higher CEC's require higher soil K tests (lb/ac), while lower soil CEC's tend to need relatively higher saturations.
- **Soil Moisture Level:** While K is central to improving a plants ability to withstand drought, dry soil greatly reduces K uptake.
- **Cation Balance:** While research does not support any significant effect from small to moderate differences in the relative amounts of K, Mg, Ca, and Na (cation ratios), exceptionally high amounts of these other cations can reduce K availability.
- **Sub-Soil K:** This is essentially the same topic as soil test level, but sub-soil tests are not normally available. However, some soils have unusually high or low amounts of available K in the sub-soil.
- **Type of Clay**: Some clay types can "Fix" more K than others. This is often reflected in, but not measured by the soil CEC
- **Soil Temperature:** Soil K uptake is reduced in cooler soil temperatures.
- **Tillage/Compaction:** Reduced tillage practices typically reduce K uptake at equal soil test levels. This is often attributed to cooler, more compacted soils.
- **Drainage/Aeration:** K availability tends to improve or be reduced as soil drainage and aeration is improved or reduced.

As shown earlier, alfalfa removes large amounts of K. Of course, we have the same soil test level concerns with K as with P. Low soil tests tend to tie-up or "fix" some portion of the applied K_2O, making it less available to crops. Being a cation, much of the soil K is adsorbed (attached to) the soil exchange complex (primarily clay and OM). Soils with higher CEC's have a larger capacity to tie-up applied K. In practical terms, you might consider K soil tests in the same way as magnetism. A low CEC is like a small magnet and a high CEC like a large one. Low CEC's, like small magnets have weak attraction and a smaller capacity to hold whatever they attract, whereas high CEC's, like large magnets, have stronger attraction and a larger capacity to hold things. Like these magnets, it takes more cations to "fill-up" a large CEC and when there are relatively few cations in the soil (low soil test); the higher CEC is less prone to release them to plant roots. This is the basis of why high soil tests feed plants better than low ones.

At Spectrum, we assign soil K status according to the amount of K and the soil CEC. The following table illustrates our soil K status ranges. The soil test values listed in the soil K status table are the center of each range.

Soil K Status Tables								
CEC	**0.1**	**5**	**10**	**15**	**20**	**25**	**30**	**35+**
	Potassium (lb./acre)							
Low	90	90	120	150	165	180	200	225
Medium	180	180	240	300	340	380	400	452
Good	270	270	380	460	530	570	615	660
High	400	400	545	690	777	864	930	978
V High	401+	401+	546+	691+	778+	865+	961+	979+

Many agronomists suggest that in order to buildup soil test K, you should apply 3 or 4 1b/ac K_2O per 1 lb (or 2 ppm) of expected soil K increase. This is "surplus" K_2O, or that which is in addition to the needs of the crop. While this is a reasonable recommendation in many situations, research indicates that there can be a wide range of buildup rates. A couple of examples that indicate the range in buildup efficiency are…

8.5 lb. /ac K_2O to increase the soil test 1 lb. K/ac, Kelling, K.A. and P.E. Speth, U of WI, 1997
1.8 to 10.6 1b. /ac K_2O to increase the soil test 1 lb. K/ac, Johnston, et al, Univ. of Natal, RSA, 1999

Soil K buildup in a given field depends on the initial soil test plus the type and amount of clay in the soil. Purdue Univ. looked at this subject and found the following. They don't report results in terms of K_2O applied vs. soil test buildup, but the "% Fixed" values are a good indication of how much of the applied K_2O can be converted into less available forms for the next season. Of course, you can assume that more of the applied K is fixed on lower initial soil test levels. It is also safe to assume that soils with higher CEC's will require higher rates of K_2O to increase the soil K levels 1 lb/ac.

Soil Type vs. Applied K_20 Fixation over 7 months	
Soil Type	**% Fixed**
Crosby Silt Loam	11 to 33
Zanesville Silt Loam	7 to 37
Brookston Silty Clay Loam	58 to 68
Chalmers Silty Clay Loam	16 to 36
Vigo Silt Loam	10 to 20
Application Rate = 400 lbs/A K_20 Purdue Univ.	

Like P, soil test K reduction works in a similar manner, but in reverse, to soil buildup. The same alfalfa study by Wells and Dollarhide (University of Kentucky) looked at soil test K reduction by growing alfalfa without fertilizer. The 16 different soils averaged a reduction in soil K of 1lb/a for every 3.2 lb of K_2O removed. Also like the P study there was a significant range in results. The basic trend showed soil K drawdown rate ranging from 1 lb. soil K reduction per approximately 2 lb of K_2O removed up to 1 lb soil K reduction per approximately 5 lb of K_2O removed. Soils with higher initial soil K tests were drawn down more easily than those with lower initial starting K levels. This is logical because a higher soil K test at a given CEC will contain a greater portion of that K held more loosely, thus more readily removed by the crop. This, of course typically is the reason for higher alfalfa yields at higher soil test K levels.

Our K_2O recommendation program is intended to achieve the listed yield goals while making some improvement in the soil test. However, due to the very large amounts needed to improve some soils, we have not always recommended the entire buildup needs.

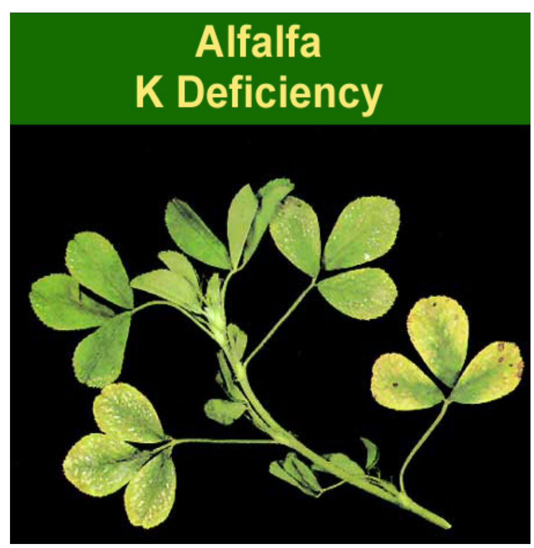
Alfalfa-Fall Seeding, Crop 10	
Soil Applied K_2O Recommendations	
	All Yield Goals
Soil K Status	lb K_2O/acre
Low	240
Med	120
Good	60
High	0
V High	0

Alfalfa Topdress, Crop 11						
Soil Applied K_2O Recommendations						
	Yield Goal (T/acre)					
	3	5	7	9	11	13
Soil K Status	lb K_2O/acre					
Low	394	494	635	784	904	999
Med	334	434	604	724	844	964
Good	150	250	420	540	660	780
High	0	0	0	60	120	240
V High	0	0	0	0	0	0

A comment is included to split apply K_2O if recommendation is more than 400 lb/ac.
Spring seeded alfalfa is crop number 134 and the K_2O recommendation is the same as crop 11-Alfalfa Topdress

One word of caution: Dairymen who have followed this K program to achieve significantly higher alfalfa yields have found that the higher K content of their higher yielding alfalfa caused them to exceed the desirable K intake of their dry cows. Dairymen facing this dilemma should contact a nutritionist about the possibilities of changing their feed rations to adjust for the increased K in the alfalfa. Potassium deficiency symptoms and leafhopper damage have sometimes been confused. The following photo’s of each show the difference.

As the photo’s show, K deficiency tends to be a more leaf-margin symptom. Many references list the deficiency symptom as a spotted chlorosis around the tip and leaflet edges. However, others indicate that there can be a general yellowing in the same area that may not appear as distinct spots. Potassium symptoms may also have more of a white color than yellow, but both examples can be found. Leafhopper damage tends to be primarily a leaf-tip and mid-rib symptom (sort of a V formation as opposed to an inverted V in K deficiency).



Secondary Nutrients

By definition, alfalfa and all crops remove less secondary nutrients than the major nutrients. If the soil is lacking in any of these nutrients, yield and quality will suffer.

Alfalfa Nutrient Removal			
	Ca	**Mg**	**S**
lb. /ton	28	5.25	6.61
lb. /10 ton	280	52.5	66.1

Calcium (Ca)

It is very unlikely that alfalfa producers will benefit from Ca applications beyond that needed from lime to maintain a proper soil pH. Assuming that the soil pH is adequate, there is little benefit to increasing the soil Ca saturation to some artificial level above 50%. For example, there is no evidence to suggest that 70% Ca saturation is better than 65%, nor that 65% Ca saturation is better than 55%. In fact, if excess Ca applications result in a Ca:P ratio in the feed that is too high, it can result in poor nutrition for the livestock. Soils with the correct pH for alfalfa will almost always have soil Ca saturations well above 50% and are unlikely to benefit from additional Ca applications.

The plant pictured below is showing severe Ca deficiency. Visual Ca deficiency symptoms are exceptionally rare in the fields. Symptoms include deformed leaves and growing tips. Calcium shortages (as opposed to visual deficiencies) in the field are normally not detected without the use of plant analysis.

Function

- Proper cell division and elongation
- Proper cell wall development
- Nitrate uptake and metabolism
- Enzyme activity
- Starch metabolism

Factors Affecting Ca Availability

- **Soil pH:** Acid soils have less Ca, and high pH soils normally have more. As the soil pH increases above pH 7.2, due to additional soil Ca, the additional "free" Ca is not adsorbed onto the soil. Much of the free Ca forms nearly insoluble compounds with other elements such as phosphorus.
- **Soil CEC:** Lower CEC soils hold less Ca, and high CEC soils hold more.
- **Cation competition:** Abnormally high levels, or application rates of other cations (principally Mg or K), in the presence of low to moderate soil Ca levels tends to reduce the uptake of Ca. However, this rarely results in a Ca shortage.
- **Sodic soil (high sodium content):** Excess sodium (Na) in the soil competes with Ca, and other cations to reduce their availability to crops.
- **Sub-soil or parent material:** Soils derived from limestone, marl, or other high Ca minerals will tend to have high Ca levels, while those derived from shale or sandstone will tend to have lower levels.

Ca Recommendations

Fertilizers	Approx. % Ca.	Typical Recommendation Ranges of Product
Gypsum	18-22	500 to 1,500 lb/ac
$CaCI_2$	36	5-8 lb/ac Foliar
$Ca(NO_3)_2$	19	10-15 lb/ac Foliar
Ca-Chelates	3-5	0.25-3 gal/ac Foliar

Calculating Gypsum Requirement

There are various purposes for applying gypsum and each has a specific method for developing a recommendation. There may also be more than one legitimate method used to make recommendations for each purpose. The following are some of these methods.

Gypsum is recommended for two primary purposes. They are…

- To remove excess sodium (Na)
- To build soil Ca levels when a pH change is not desired.

Reducing Soil Sodium (Na)

- Reducing Na to a generally acceptable level: Lb. gypsum/acre = C.E.C. x (%Na sat. - 5) x 18
- Reducing Na to a particular saturation percent:
  - EXAMPLE: Assume that the soil CEC is 20 (meq/100 grams) and the Na concentration is 40%. You want to lower the Na concentration to 10%, or eliminate 30% of the Na saturation (30% of 20 meq/100 grams = 6 meq of exchangeable Na/100 grams of soil). Multiply the milliequivalents of exchangeable Na by 0.85 tons of gypsum to get the required application of gypsum ($6 \times 0.85 = 5.1$ tons of gypsum/acre). Typically, commercial gypsum is not 100% efficient in displacing Na, and some authorities suggest using an 80% efficiency factor. Doing this results in our example changing as follows...$5.1 \div 0.80 = 6.38$ tons per acre. If your irrigation water or soil contains gypsum, you can deduct these amounts from the required rate of gypsum to apply.
- Calculating gypsum to offset Na in irrigation water: Gypsum requirements can be calculated from the residual sodium carbonate (RSC) value of the irrigation water from the following equation.
- RSC × 234 = pounds of gypsum required to offset the excess sodium in 1 acre foot (325,852 gallons) of irrigation water

Remember, gypsum alone does not solve a high Na problem; you must apply adequate irrigation water to leach the displaced Na out of the root zone.

Increasing Soil Ca Saturation

While we do not support the concept of applying Ca to reach a specific soil saturation; if you choose to follow this practice, the following formula may be helpful. It was published by N. Carolina State University to determine the amount of Ca needed to reach a specific soil Ca saturation. Keep in mind that each soil type will behave a little differently, so this formula should only be considered an approximation of the needed gypsum.

$$\text{Lb. gypsum/acre} = \text{C.E.C.} \times (\text{desired \% Ca saturation} - \text{present \% Ca saturation}) \times 18$$

Magnesium (Mg)

Magnesium availability also often correlates to soil pH. However, some low CEC soils may have limited amounts of available Mg. Add to this the high K_2O rates needed for alfalfa and you may find instances of Mg shortages. These situations are easily addressed with the use of dolomitic lime and K-Mag as the situation directs.

Function

Magnesium is essential for many plant functions. Some of them are…

- Photosynthesis: Mg is the central element of the chlorophyll molecule.
- Carrier of Phosphorus in the plant
- Magnesium is both an enzyme activator and a constituent of many enzymes
- Sugar synthesis
- Starch translocation
- Plant oil and fat formation
- Nutrient uptake control
- Increase Iron utilization
- Aid nitrogen fixation in legume nodules

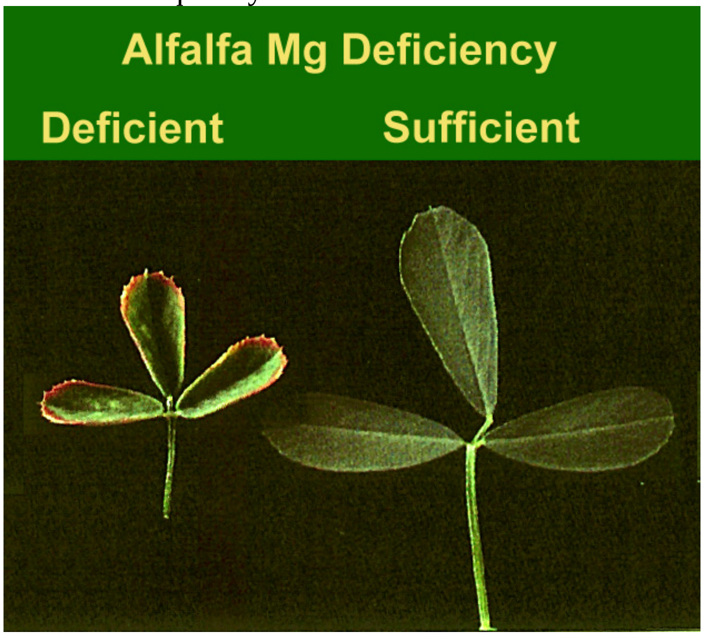
Factors Affecting Availability

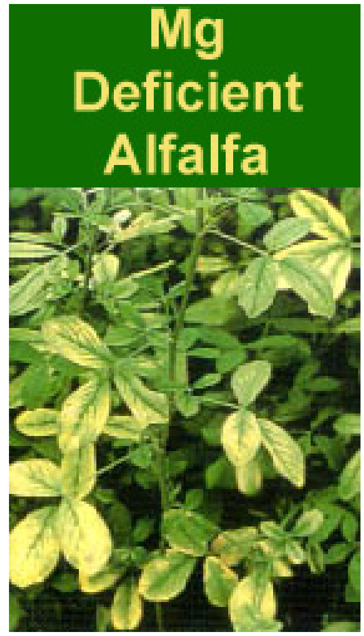
- **Soil Mg content:** Soils inherently low or high in Mg containing minerals
- **Soil pH:** Low soil pH decreases Mg availability, and high soil pH increases availability
- **Soil CEC:** Low CEC soils hold less Mg, while high CEC soils can hold abundant Mg. However, if a high CEC soil does not happen to have strong levels of Mg, it will tend to release less of the Mg that it holds to the crop.
- **Cation competition:** Soil with high levels of K or Ca, or high ratios of K and/or Ca to Mg, will often provide less Mg to the crop
- **High cation applications:** High application rates of other cations, especially K, can reduce the uptake of Mg. This is most common on grasses, and corn seems to be the most sensitive grass.
- **Low soil temperatures**
- **Soil Mg:Mn ratio:** High available Mn can directly reduce Mg uptake. This may be independent of the acid conditions normally associated with excess available Mn in the soil.

While there is ample data to suggest that crop growth is not particularly sensitive to the soil Ca:Mg ratio, there does seem to a relationship between K and Mg. Our experience has shown the following.

Soil K:Mg Ratio (lb/ac)	**Effect**
0 – 1.0	Mg availability controlled by soil Mg level and soil pH.
1.1 – 1.5	Corn begins to have Mg uptake problems at the lower end of this range and other grasses begin to have problems at the upper end.
1.5 +	Many non-grass species like alfalfa begin to have problems with Mg uptake.

Visual symptoms of Mg deficiency occur first and most severely on older/lower leaves, progressing up the plant as the deficiency persists. In this, alfalfa is similar to most other plants. Leaves will typical have interveinal chlorosis, but sometimes, leaf edges may show a reddish color. Plant growth is often stunted and stems are frequently weaker than normal.





When Mg problems occur and lime is needed, dolomitic lime is essential. However, lime is somewhat slow to correct problems. Where faster response is needed, use a readily soluble source of Mg fertilizer.

Calcium to Magnesium Ratio

Over the years, a significant amount of conversation and salesmanship has revolved around the concept of the ideal soil Ca:Mg ratio. Most of the claims seem to be for some specific "ideal" ratio between 5:1 and 8:1

Some of the claims are that the correct soil Ca:Mg ratio will…

- Improve soil structure.
- Reduce weed populations, especially foxtail and quackgrass, and improves forage quality.
- Reduce leaching of other plant nutrients.
- Generally improve the balance of most soil nutrients
-

It is reported that the first publication of an ideal Ca:Mg ratio came from New Jersey in 1901. This early work recommended a "total" (not "available") Ca to Mg ratio in the soil of about 5:4. As we know today, and was recognized soon after that publication, an analysis of the total soil content of a nutrient bears little relationship to its crop availability. Later, again in New Jersey, it was reported that the "ideal" alfalfa soil should have cation saturation's of 65% Ca, 10% Mg, 5% K, and 20% H. In the years since this claim was made, there have been many instances where record breaking alfalfa yields, not to mention other crops, have been produced on soils without this supposedly ideal cation balance. Fertile soils commonly have a Ca:Mg ratio between 5:1 and 8:1. However, this does not mean that any specific Ca:Mg ratio is required, or is better, or is even related to yield. Research results show that this ratio can be as narrow as 2:1 or as wide as 11:1 without negative effects, assuming that there is an adequate amount of each nutrient in the soil.

In the mid-1980's the University of Wisconsin conducted research into the effect of Ca:Mg ratio on alfalfa growth. They found that while the Ca:Mg ratio in the plant tended to reflect the soil Ca:Mg ratio, the plant content (the % of Ca and Mg in the tissue) of these nutrients was affected much less and in no case did the soil or plant ratio affect yield. In this work the plant Ca and Mg contents were never below the respective critical levels for each nutrient, even though the soil Ca:Mg ratios ranged from 2.28:1 to 8.44:1. The researchers concluded that, assuming there are adequate levels of Ca and Mg present in the soil, variations in the Ca:Mg ratio over the range 2 to 8 have no effect on yield.

In 1999 the University of Missouri, Delta Research Center published the results of an investigation into the effects of soil Ca:Mg ratio on cotton. They amended plots with gypsum or Epsom salts to create soil Ca:Mg ratios between 3.8:1 and 11.7:1. They found that cotton yields were not significantly different between treatments.

McLean, et al in Ohio, could find no specific cation ratios that predicted sufficiency or shortages of K, Mg, or Ca in several crops.

Cation Ratio	**Yield Group**	**Ranges of Soil Ca:Mg Ratio (x:1)**			
		Corn	**Soybeans**	**Wheat**	**Alfalfa**
Ca:Mg	High	5.7 – 20.6	5.7 – 14.9	5.7 – 14.0	6.8 – 26.8
Ca:Mg	Low	5.4 – 18.8	2.3 – 16.1	6.8 – 21.5	5.7 – 21.5

Notice in McLean’s work that the Ca:Mg ratios is essentially the same for both the high and low yielding groups of all crops. There is no trend or bias in the relationships between the Ca:Mg ratio and the relative yields of any crop. The researchers concluded that the soil Ca:Mg ratio had little or no effect on yield.

According to Dr. Stanley Barber, Purdue Univ., **“There is no research justification for the added expense of obtaining a definite Cam ratio in the soil…Research indicates that plant yield or quality is not appreciably affected over a wide range of Cam ratios in the soil.”**

Sulfur (S)

Alfalfa is considered a high-response crop to sulfur. Most dark colored soils are able to provide very large amounts of sulfur (S). However, on light colored soils and those with low CEC, alfalfa often responds to added S. Alfalfa and all other plants utilize the sulfate (SO_4^-) form of sulfur. Any elemental Sulfur (S) that is applied must be converted to SO_4^--S prior to uptake. This can be a rather slow process since it is performed by bacteria which depend on good moisture and temperature, plus time to accomplish this task. Therefore, if a quick S response is desired, sulfate-S is the preferred choice. An additional negative aspect of using elemental S is that as it is converted to the available SO_4^- form, acid is produced. At normal application rates (up to 30 lb. S/a), this should not be a significant problems, but many fertilizers that already contain SO_4^--S do not have this problem.

Function

- A structural component of protein and peptides
- Active in the conversion of inorganic N into protein
- A catalyst in chlorophyll production
- Promotes nodule formation in legumes
- A structural component of various enzymes
- A structural component of the compounds that give the characteristic odors and flavors to mustard, onion and garlic

Factors Affecting Availability

- **Soil CEC:** Sulfur is leach able so low CEC soils tend to lose S from the topsoil. Low CEC soils are typically low in OM; therefore these soils are often low in sulfur.
- **Soil OM:** Organic matter is a reservoir for S
- **Cold Soil:** The conversion of various forms of S to the available sulfate (SO_4) form is a microbial process which is dependent on temperature. Low soil temperatures slow this process.
- **Poor Drainage:** The conversion of various forms of S to the available sulfate (SO_4) form is a microbial process requiring oxygen, therefore saturated soil slow this process.
- **Pollution:** Soil that has been subjected to high levels of S deposition from industrial sources over the years is often higher in available S.
- **Irrigation Water:** Irrigation water may contain high levels of S. Conversely, irrigation of low CEC soils can leach S out of the root zone.

Sulfur uptake by most plants is highly correlated with the N content in the plant tissue. This is probably related to the N:S ratio of the proteins and other compounds formed by the plants. The practical result of this relationship is that when plants are low in N, they will likely be low in S, regardless of the S provided by the soil or fertilizer program. Plants that have adequate N, but low S are indications of a true S shortage. Therefore, applying extra S to plants that are short of N is not normally effective.

There has been some work to indicate that excessive amounts of SO_4^- can limit B uptake. This is apparently due in some part to anion competition. Since alfalfa is highly responsive to both nutrients, it is probably more likely to have this problem. The obvious answer is to avoid excessive S application, or insure that adequate B is supplied when S is applied. Visual deficiency symptoms of S deficiency as illustrated in the picture to the right include a generally lighter green color, possibly more pronounced on the younger leaves, and a general stunting of the entire plant.

Micronutrients

Micronutrients include boron (B), copper (Cu), manganese (Mn), Zinc (Zn), iron (Fe), molybdenum (Mo), and chlorine (Cl). Maintaining the soil pH near 7.0, as required by alfalfa, can cause micronutrient shortages in some soils. Therefore, it is important to counter this with appropriate fertilizer programs. All of these nutrients, except Mo and Cl become less available as the soil pH increases. Maintaining alfalfa soil at a pH much above 7.0 is unnecessary and can cause serious problems with micronutrient and P availability. Therefore, a well designed liming program can provide both yield gains and save some money by eliminating unnecessary micronutrient purchases.

The following "Relative Response" chart ranks the micronutrients according to the sensitivity of alfalfa to their shortage. A low or unknown response listing does not mean that alfalfa does not need that nutrient. Alfalfa needs all of these nutrients, so if a soil test, or experience suggests a need for them, they should be applied.

Relative Response of Alfalfa to Micronutrients						
Boron	**Copper**	**Iron**	**Manganese**	**Zinc**	**Molybdenum**	**Chlorine**
High	High	Medium	Medium	Low	unknown	unknown

It isn't useful to work with micronutrient removal rates, because there is little correlation between removal and the rate needed to get a response. This is due to the typically very large interactions of micronutrients in the soil, causing a need for applications much higher than removal amounts. For example, the Zn content of the above-ground portion of alfalfa typically ranges between 20 to 50 ppm. This equals about 0.04 to 0.10 lb. Zn/ton or 0.4 to 1.0 lb Zn/10 tons. To get this amount of Zn into the crop when the soil is deficient, it will likely require the application of from 5 to 15 lb. of Zn/acre. This represents an application to removal ratio of from 13:1 to 38:1.

In some cases, the simple soil test level of a micronutrient may not be especially well related to plant availability. Other interacting factors such as soil pH, other nutrients, drainage, soil temperature, and others can have a major impact on the availability of most micronutrients. Therefore, growers and their advisors must consider all aspects of a soil test and other conditions to determine the best micronutrient program. One general principle is that crops are not likely to respond to micronutrients until the major nutrient needs are satisfied. Where well designed high yield programs are being used, alfalfa may respond to any of the micronutrients.

Boron (B)

Boron is probably the most widely applied micronutrient in alfalfa production. It is widely accepted that alfalfa responds well to annual applications of B in nearly all soils and soil B levels. One soil factor that contributes to the need for B on alfalfa is that B is less soluble at the higher pH requirements of alfalfa. This may contribute to retaining some additional B against leaching, but it may also reduce the availability to crops somewhat. Usually, 2 to 3 lb. B/ac per season is required for adequate yields, and more is not necessarily better.

Function

- Maintaining a balance between sugar and starch.
- The translocation of sugar and carbohydrates.
- It is important in pollination and seed reproduction.
- It is necessary for normal cell division, nitrogen metabolism, and protein formation.
- It is essential for proper cell wall formation.
- It plays an important role in the proper function of cell membranes and the transport of K to guard cells for the proper control of internal water balance.

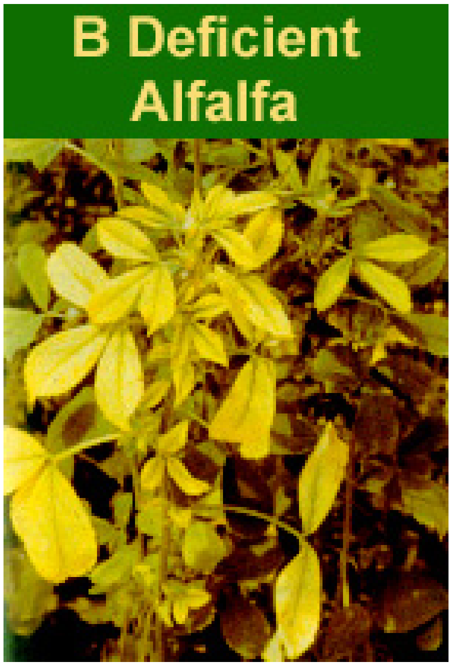
Factors Affecting Availability

1. **pH:** High pH reduces, and low pH enhances B availability.
2. **Leaching conditions:** B is mobile, so coarse soils and high rainfall may cause temporary soil shortages.
3. **Low OM:** Organic matter is a reservoir for B, and many other nutrients
4. **Low Moisture:** Boron uptake is in part determined by water uptake rate, therefore drought reduces B uptake. Also, B deficiency reduces root growth, thus aggravating the B stress.
5. **Soil Ca:B Balance:** Some work has indicated that high soil Ca levels, independent of soil pH can reduce B uptake. In most situations however, high soil Ca will be accompanied by higher soil pH, and the pH effect will dominate. *In some cases of B toxicity, an application of a soluble form of Ca has reduced the toxic effects.*
6. **K: B Balance:** Work has show that high K rates can sometimes depress corn yields if B is limiting.
7. **Snob and P: B Balance:** Work with barley showed that Zn applications can reduce B accumulation. This same work showed that high P applications increased B accumulation.
8. **N Stress:** Low N availability decreases the vigor of plants to an extent that it may fail to take up adequate amounts of many other nutrients. Boron uptake can be affected in this way.

	Soil B (hot water, ppm)				
	0.3	**0.4**	**0.5**	**0.6**	**0.7**
Soil pH	**Alfalfa Yield T/ac (12% H_2O)**				
5.7	1.10	1.33	2.16	3.58	5.61
6.2	2.33	2.55	3.39	1.40	6.83
6.7	3.33	3.57	4.39	5.86	7.85
7.2	4.14	4.36	5.19	6.61	8.64
7.7	4.73	4.95	5.77	7.20	9.24

Researchers at Texas A&M University produced the accompanying table which represents projected yields at various soil pH and soil test B combinations. ***This data assumes that 2 lb. B/ac will be applied to the crop.*** The chart is based on a single soil type and others responded differently in that study. We might question the projection of the highest yields occurring at a soil pH of 7.7, since other negative consequences can occur at such a high soil pH. However, it illustrates the importance of soil and applied B to alfalfa.

Alfalfa has a strong demand for both B and S. Both are anions in their available forms. Some work suggests that high levels of available or applied SO_4-S can limit B uptake in alfalfa. This could be a simple competitive reaction between negatively charged anion nutrients, or something more. Given the importance of both nutrients to alfalfa, it may be wise to make sure that adequate B is supplied whenever significant amounts of S are recommended.



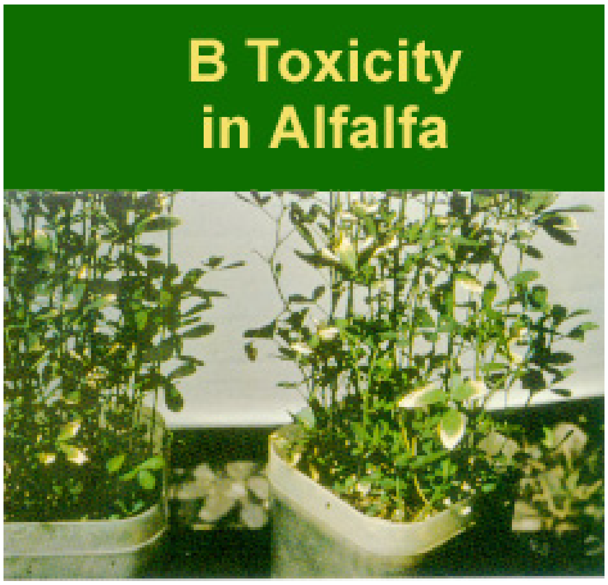
Boron deficiency will be a chlorosis (yellowing) of the youngest leaves on each stem. The stems length in the chlorotic tips is likely to be much shorter, giving the tips the appearance of a “rosette” or “bunchy” growth pattern. In some cases, this appearance might be confused with leafhopper damage.

As the severity of the deficiency increases, the affected leaves could take on a bronze appearance and the stem growing tips could die.

Toxicity

As with most micronutrients, B toxicity is possible. Boron toxicity will normally appear as a “burning” or whitening of the leaf edges of the lower leaves. It is not possible to accurately list the soil B test or fertilizer rate at which B toxicity will occur in any particular situation. However, rates of elemental B around 2 to 3 lb/ac will normally supply adequate B to the crop and rates under 5 lb of elemental B/acre are not likely to cause toxicity problems.

A plant analysis can confirm both deficiencies and excess. More importantly, plant analysis can find yield-robbing shortages long before they cause visual symptoms.



Copper (Cu)

While alfalfa is listed as being highly responsive to Cu, in normal conditions it is unusual for Cu to be limiting. However, a grower won't know if he has a Cu problem until he either... 1) takes some plant samples, or 2) applies some Cu to a trial area to evaluate any response. A plant sample is a much better tool for making these decisions.

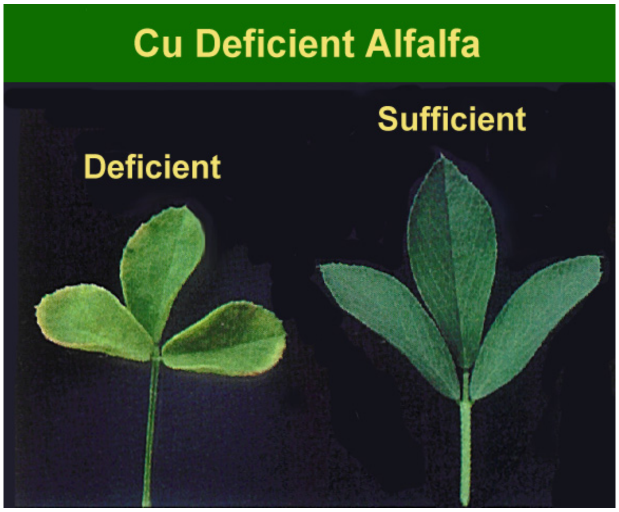
Function

- It functions as a catalyst in photosynthesis and respiration.
- It is a constituent of several enzyme systems involved in building and converting amino acids to proteins.
- Copper is important in carbohydrate and protein metabolism.
- It is important to the formation of lignin in plant cell walls which contributes to the structural strength of the cells, and the plant.
- Copper also plays a major role in a plants ability to protect itself from various diseases.

Conditions Favoring Shortages

- Low native soil Cu level and/or high soil pH, OM, P, Zn, Fe, and sometimes Mn.

Deficiency Symptoms



Symptoms appear on the youngest leaves. They include stunted growth with smaller chlorotic leaflets that may tend toward a grayish or whitish color. Sometimes there tends to be spots in the mid-leaf. Leaves and growing points may be malformed and may appear to be suffering from drought stress.

Copper Fertilization

Copper recommendations range from 1 to 10 lb/ac of elemental Cu. Growers should avoid indiscriminate use of Cu because it builds up in the soil over time. Confirm the need for Cu with a plant analysis and monitor any soil buildup with annual soil and plant samples. It should be possible to make the necessary Cu applications for a few seasons, and then discontinue Cu use for the foreseeable future.

Copper Toxicity

The major effect of Cu toxicity is root damage, which can result in several different foliage symptoms. Classic Cu toxicity symptoms include severe chlorosis of the growing tips and very young leaves. Excess Cu often results in the death of fine roots and root hairs, producing an appearance similar to that of some herbicides.

Excess Cu also inhibits the uptake of P, Fe, Mn, and Zn, resulting in the possibility of deficiency symptoms of any of these nutrients. The accompanying photo of foliar symptoms of Cu toxicity may well be a deficiency of Fe or Zn, although the source did not label it as such.

Since root damage is commonly associated with Cu toxicity, as the amount of available Cu in the soil is increased, the root damage begins to limit plant uptake of Cu. This can limit the amount that might be found in the foliage. A plant analysis of alfalfa with Cu toxicity will likely find somewhat high Cu levels, but the levels are not likely to be dramatically high

If you suspect Cu toxicity, it is important that you take paired soil and plant samples from the same area, and include full information on any source of Cu (fertilizer, manure, sludge, livestock footbath water, and some fungicides) that may have been applied in the past few years.

Manganese (Mn)

After B, Mn can be one of the more common micronutrient problems in alfalfa. Where this occurs, it is often the result of an excessively high soil pH.

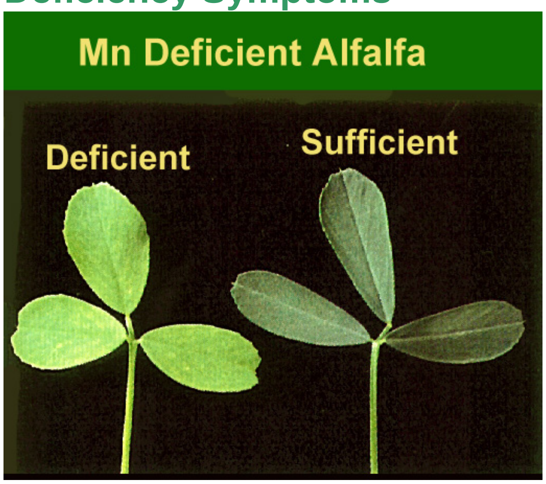
Function

- The assimilation of carbon dioxide in photosynthesis.
- It aids in the synthesis of chlorophyll and in nitrate assimilation.
- Manganese activates fat forming enzymes.
- It functions in the formation of riboflavin, ascorbic acid, and carotene.
- It functions in electron transport during photosynthesis.
- It is involved in the Hill Reaction where water is split during photosynthesis.

Conditions Favoring Shortages

High soil pH (typically above pH 7.2), rapid change in soil moisture content, excess available K, Fe, Cu, Zn, or sodium (Na).

Deficiency Symptoms



Because Mn is not translocated in the plant, deficiency symptoms appear first on younger leaves. The most common symptom is interveinal chlorosis. However, alfalfa typically does not exhibit as sharp a color distinction between the greener veins and the more yellow interveinal area, when compared to other plants. This can result in the symptom being confused with other nutrient problems.

Manganese Fertilization

Manganese fertilization presents a special problem with alfalfa and other forage crops. Deficient soils have a very large capacity to convert any applied Mn to unavailable forms. University research and our own research plots have shown that when applied as broadcast, Mn rates up to 30 lb of elemental Mn per acre may be required to provide adequate Mn uptake by most crops. In the same conditions, row applied Mn worked as well or better at many times less that the broadcast rates, and foliar rates were successful at much lower rates yet. Unfortunately, banded applications of Mn may not be practical for alfalfa or most forage species, so we are left a choice between broadcasting high rates of Mn or multiple foliar applications.

On-farm research at Rutgers University in New Jersey illustrates the differences between broadcast and foliar applied Mn on alfalfa. Broadcast soil applications of 20 lb. Mn/ac from manganese sulfate, applied once in the spring at the start of new growth, and was compared with foliar treatments of 0.5 lb of Mn/ac applied foliarly before each harvest when the plants were about 6” tall. Compared to the untreated control plots, the soil application of 20 lb Mn/ac increased the season’s yield by 0.2 T/ac, while the foliar treatments increased the yield 0.4 T/ac. While these may not seem like dramatic increases for the foliar treatments, remember that the foliar program required significantly less Mn. The researchers noted that foliar applications may be made more cost-effective by combining one or more sprays with a pesticide application. They also suggested that a combined program may be even more cost effective. For example, a spring soil application of 10 lb Mn/ac, made with other fertilizer, followed by several foliar applications during the remainder of the year may be best in some situations. It should always be noted that you should check the compatibility of all products when combining them in spray solutions.

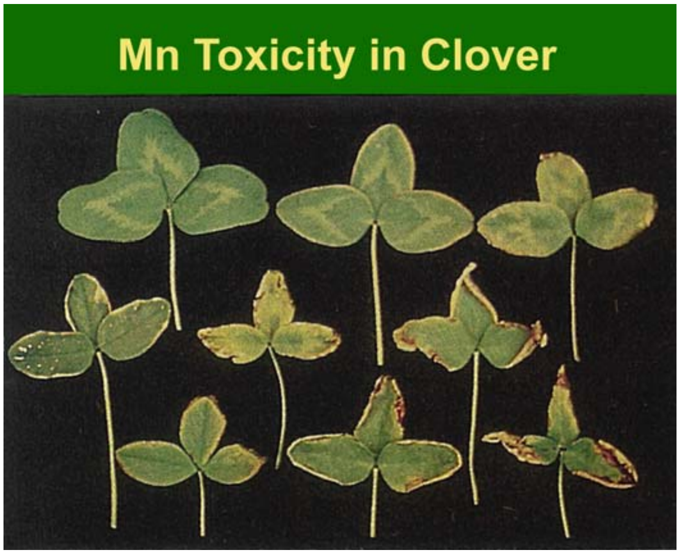
Having worked with high soil pH situations for many years, we have found that it often requires more than the 0.5 lb Mn/ac in foliar applications to satisfy the crops needs. Various sources suggest foliar Mn application rates from 0.5 to around 2 lb Mn/ac. The low end of this range may be ineffective in some situations, while the high end could cause tissue damage. If a high rate is planned, try an application on a small area to see if leaf damage occurs.

Recommended rates of Mn	
Broadcast	not recommended
Foliar	1 to 2 lb Mn/ac from $MnSO_4$, or label rate of proprietary products

As you can see, we do not recommend broadcast applications of Mn. However, as we have seen, high rates of broadcast Mn can have positive results. It should be understood that the high rates of broadcast Mn rarely increase the soil Mn levels or availability. Therefore, the crop will nearly always require those high rates annually over the life of the stand. Given this situation, it seems more reasonable to depend on foliar Mn applied during each alfalfa regrowth period.

Manganese Toxicity

Manganese toxicity is almost always caused by acid soils. It is possible to have a temporary "flush" of excess available Mn in soils in during times when they are water-saturated for an extended period. This temporary excess will typically quickly revert to normal when the soil dries out.



Alfalfa is noted by several authorities as being very intolerant of, or sensitive to an excess of Mn. Unfortunately, at the time of this writing, there were no pictures of Mn toxicity in alfalfa available. However, it should respond similar to clover as shown in the accompanying photos.

Clover exhibits direct Mn toxicity as a marginal chlorosis and ultimately death of the younger leaves. As the margins of the leaves deteriorate, it causes a "cupping" of the affected leaves. However, excess tissue Mn is just as likely to cause a deficiency in a competitive nutrient such as Fe, Cu, and/or Zn, causing the plant to exhibit the deficiency symptom of that nutrient. Soils with a pH below 6.0 will also begin to have excessive levels of soluble aluminum (Al), which can damage plant roots. When this happens, the plants could exhibit the visual symptoms of a deficiency of an immobile nutrient like P or Cu. In such soils there is also a naturally low level of Ca, Mg, and sometimes K. Any of these could cause their own deficiency symptoms. In the field, the acid soils that cause Mn toxicity are likely to have crops with one or more of several deficiencies or toxicities at the same time.

Zinc (Zn)

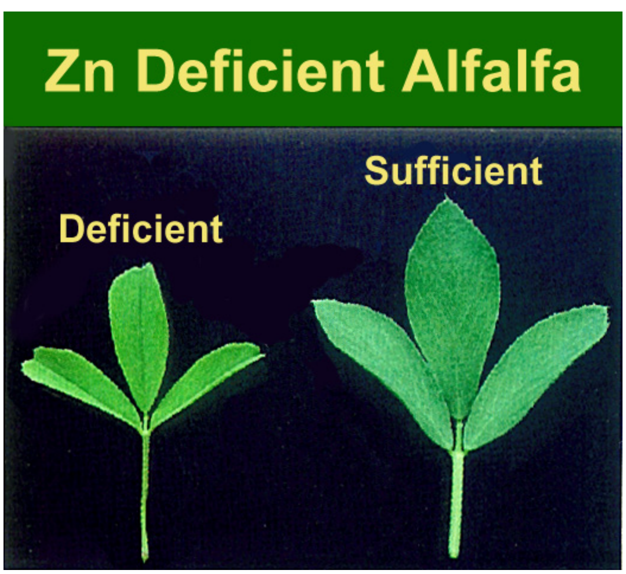
Function

- Production of Auxins, an essential growth hormone.
- It activates enzymes in protein synthesis, plus is involved in the regulation and consumption of sugars.
- It is necessary for starch formation and proper root development.
- Zn influences the rate of seed and stem maturation.
- It is necessary for the formation of chlorophyll and carbohydrates.
- Adequate amounts in the tissue enable the plant to withstand lower air temperatures.

Factors Affecting Zn Availability

- **Soil pH:** Zn availability often decreases as pH increases, however this effect is not universal.
- **Zn:P Balance:** High levels of soil P are commonly responsible for Zn deficiencies.
- **Organic Matter:** Organic matter is a source of Zn, and the organic compounds in O.M. can chelate inorganic sources of Zn and increase their availability.
- **N Stress:** Low N availability decreases the vigor of plants to an extent that it may fail to take up adequate amounts of many other nutrients. Zinc uptake can be affected in this way.
- **Water-logged Soil:** While Zn does not undergo the valence changes that Mn does in saturated soils; research has shown that rice cannot take up Zn as effectively under flooded conditions. The causes of this condition appear to be applicable to other crops in one degree or another.
- **Zn:Cu Balance:** Plant roots appear to absorb Zn and Cu by the same mechanism. This causes interference in the uptake of one when the other is in excess in the root zone.
- **Zn:Mn Balance:** Research results have indicated evidence of an incidence of interactions between Zn and Mn. Some results indicate an antagonistic relationship, while others indicate a sympathetic relationship. Certain work indicates that specific cultivars within species may have a stronger reaction to soil Zn:Mn balances.
- **Zn:Mg Balance:** It has been reported that additions of Mg can increase the uptake of Zinc. **Zn:As Balance:** While rare, high levels of arsenic (As) in the soil, as can be found in old orchard soils, can seriously inhibit both Phosphorus and Zinc uptake.

Deficiency Symptoms



Deficient plants will be stunted with smaller terminal leaves, have shortened internodes, and have a somewhat lighter green color. The shortened internodes may result in somewhat of a “rosette” formation of the terminal leaves.

Toxicity

Alfalfa can tolerate significantly higher levels of Zn than needed and toxicity is exceptionally rare. It has occurred in crops grown near abandoned zinc mines. Reported symptoms are chlorotic and necrotic leaf tips, interveinal chlorosis in new leaves (difficult to identify in alfalfa), retarded growth of the entire plant, and injured roots resemble barbed wire. However, excessive Zn availability or uptake could just as easily cause deficiencies of other nutrients, especially P, Cu, Mn, and sometimes Fe. This may result in one or more of these deficiency symptoms being the only apparent symptom. Liming and the_application of Phosphorus fertilizers have been used to reduce Zn availability.

Zinc Fertilization

Zinc Recommendations	
Broadcast	2 to 16 lb/a
Foliar	0.25 lb/a

Zinc is sometimes applied broadcast at much higher rates than listed above. Normally this is done to correct the soil Zn level in one treatment. This approach can be effective in correcting Zn problems for many years. Zinc-oxides and oxy-sulfates are satisfactory for buildup purposes, but for predictable responses in the year of application, either sulfate or chelate forms should be used. Remember, as far as the soil application of chelates are concerned; a pound of Zn is a pound of Zn. Chelates are often less prone to causing leaf damage when applied foliar, but this is primarily because they are less efficient at leaf penetration. You can also consider the application of appropriate Zn-containing fungicides as an effective foliar treatment for mildly low leaf Zn conditions.

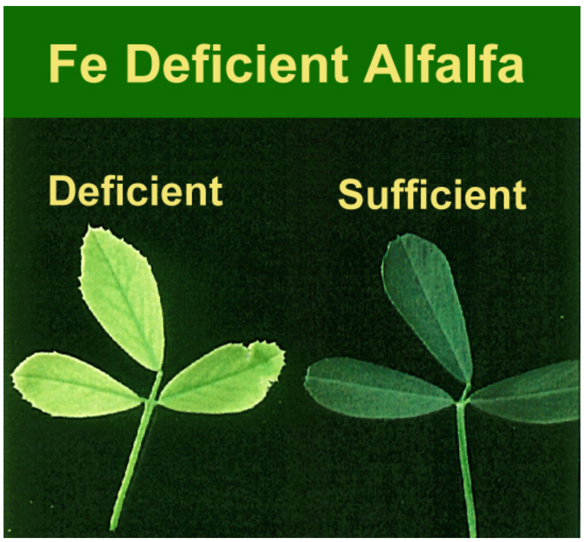
Iron (Fe)

Function

- Chlorophyll development and function.
- It plays a role in energy transfer within the plant.
- It is a constituent of certain enzymes and proteins.
- Iron functions in plant respiration, and plant metabolism.
- It is involved in nitrogen fixation

Deficiency Symptoms

Iron deficiency, or crop response to Fe is very rare in most of the United States. Iron shortages typically only occur in alkaline or sodic soils in very dry climates. The visual symptoms of Fe deficiency include Interveinal chlorosis of young leaves. Severe deficiencies may appear as if the leaf veins are also chlorotic and progressively affect the entire plant turning the leaves from yellow-green to bleached-white.



Factors Affecting Availability

- **Soil pH:** High soil pH reduces Fe availability while acid soils increase Fe availability. The high pH effect is increased in waterlogged, compacted, or other poorly aerated soils. This is the primary cause of Fe deficiency in the United States.
- **Low Soil OM:** In addition to being a source of Fe, OM compounds are able to form Fe complexes that improve availability.
- **Saturated, Compacted, or Other Poorly Aerated Soils:** In acid soils, this condition can increase Fe availability (sometimes to the point of toxicity).
- **High Soil P:** Excessive soil P, or high rates of P fertilizer, have shown to inhibit Fe uptake in many crops.
- **Form of N Applied:** Increased NO_3 -N uptake can reduce Fe uptake by causing an anion-cation imbalance in the plant.
- **Fe:Zn Balance:** Zn deficiency has been shown to increase the Fe uptake of many crops, sometimes to the point of toxicity. Conversely, high Zn availability reduces Fe uptake.
- **Fe:Mn Balance:** It is well documented that these two elements are antagonistic, and one will inhibit the uptake of the other.

- **K:Fe Balance:** K appears to play a very specific, but poorly understood role in the utilization of Fe. Some research indicates that low K availability can result in increased Fe uptake.
- **Fe:Mo Balance:** High levels of available Mo can reduce the uptake of Fe by causing the precipitation of iron molybdate on the root surfaces. This is especially important in alkaline soils where the high pH reduces the availability of Fe while increasing that of Mo.
- **Bicarbonate (HCO_3^-) :** Iron deficiency can be induced by the presence of the bicarbonate ion in the soil (saline and alkali conditions).

Toxicity Symptoms

Iron toxicity exceptionally rare. It occurs primarily in very acid soils where other toxic reactions may be dominant. As with some other nutrients, Fe toxicity is often expressed as a deficiency of another nutrient, quite often Mn. Fe toxicity can also occur when Zinc is deficient or the soil is in an anaerobic condition caused by very wet or flooded conditions. Excess Fe can result in Dark green foliage, plus stunted growth of tops and roots. Michigan State University has stated (without mentioning the crop) that “Toxic situations occur primarily on acid soils (< pH 5.0) and where excess soluble iron salts have been applied as foliar sprays or soil amendments. The first symptoms of iron toxicity are necrotic (dead) spots on the leaves”. No photos of direct Fe toxicity are available.

Iron Fertilization

Most agricultural soils provide an abundant supply of Fe to plants. Soils with a high pH, the primary cause of Fe deficiency in this country, have a great capacity to tie-up any additional soil-applied Fe.

Iron Recommended Rates	
Foliar**	1.0 to 2.0 lb./ac
**Foliar spray solutions should include a wetting agent and have an acid pH. Check mixture for precipitation before using	

Both chelates and citrate acidified (reduced) sulfates are effective for foliar applications. Cost is the primary factor. Avoid the use of sulfates, or spray solutions which have a rusty color. This often indicates that the Fe has oxidized and the spray material may not be fully available to the crop.

Iron presents some difficulties for plant analysis also because (1) it is often a contaminate on samples that have any dust on them, (2) Fe can exist in a leaf in a non-functional form, and (3) a crop may respond to foliar Fe due to a low Fe:Mn ratio in the tissue, even when Fe is adequate by “critical level” standards.

Be concerned if visible symptoms exist, since this indicates a serious deficiency. If you have a very high soil pH (7.5+) and you suspect Fe shortages, consider making trial foliar Fe applications to a small area of the crop.

Foliar applied Fe is essentially immobile in the plant. Therefore, new growth on a recently treated crop may be Fe deficient. In these cases, the only option is multiple and frequent foliar Fe applications.

Molybdenum (Mo)

Function

- It functions in converting nitrates (NO_3) into amino acids within the plant.
- It is essential to the symbiotic nitrogen fixing bacteria in legumes.
- It is essential to the conversion of inorganic P into organic forms in the plant.

Molybdenum is considered to be quite mobile as it moves readily in both the xylem and phloem conductive tissue of the plant. Still its highest concentration is in mature leaves because it binds readily with sulfur-containing amino-groups, sugars, and polyhydroxides which are usually in greater concentration in these leaves. It is found in the enzymes nitrate-reductase and nitrogenase which are essential for nitrate reduction and symbiotic N fixation in plants. **Adequate Molybdenum minimizes the presence of nitrites and nitrates in plant tissues.**

Factors Affecting Availability

- **Leaching Soil Conditions:** Available soil Mo is an anion, and is therefore leachable.
- **Soil pH:** Molybdenum is the only micronutrient that has increased availability as the pH increases. At a soil pH above 6.5, unnecessary Mo applications can result in Mo toxicity to the crop, to animals eating the crop, or it may induce deficiencies of an element listed below. At pH's below 6.0, availability is rapidly diminished because Mo is easily "fixed" in the soil by free $Fe(OH)_3$, $AI(OH)_3$ and Fe_2O_3.
- **Soil Saturation**: It is believed by some researchers that in saturated soils, Mo availability is increased somewhat.
- **Mo:S Balance:** Some work has shown that sulfate applications can cause a reduction in Mo uptake by plants.
- **Mo:P Balance:** Applications of P have increased the Mo content of plants in some research. It is thought that P reduces the adsorption of Mo compounds in the soil.
- **NH_4:NO_3 Balance:** Plants can often grow well in low Mo soils when fertilized with NH_4 fertilizers, as opposed to NO_3 fertilizers.

Deficiency Symptoms

- Chlorosis of leaf margins, or more general chlorosis in some cases
- fired margin and deformation of leaves due to excess NO_3
- destruction of embryonic tissue.

Foliar deficiency symptoms are somewhat rare and positive responses may occur where there are no visible symptoms. The most common early symptom is a pale yellowing resembling nitrogen deficiency, but areas may develop necrotic spots regardless of the severity of yellowing, accompanied by general stunting and misshapen leaves.

Toxicity Symptoms

Leaf yellowing or browning, sometimes leading to marginal leaf scorch and leaf abscission as found in typical salt damage. It is rare to find excess Mo uptake in most crops. Instances of this occurring are normally related to excess or unnecessary Mo fertilizer application. Excess plant Mo can lead to molybdenosis in livestock.

Molybdenum Fertilization

Most analytic laboratories do not include soil or plant Mo analysis in their routine packages. The more capable labs may offer it as a special request. At this time the correlation between extractable Mo in the soil and crop response is the weakest of all the essential nutrients. Therefore, agronomists do not have well defined soil test recommendation systems for Mo. Plant analysis is better but, due to limited research, the "sufficiency range" in plants is quite broad. Since Mo seed treatment is inexpensive and effective, most agronomists recommend this practice for legumes for insurance against a shortage. Alfalfa and other crops requiring a relatively high soil pH often respond to Mo applications when the soil pH is too acid. Where the soil pH is above 6.5, Mo response is much less common and the potential for toxicity from soil or foliar applications increase.

Typical Application Rates of Sodium Molybdate (not elemental Mo)	
Broadcast	6 to 12 oz./acre
Foliar	1 to 3 oz./acre
Seed Treatment	½ to 1 oz./acre

The seed treatment is preferred with direct seeding. However, foliar application is favored for transplants. Broadcast applications for transplants are effective only where the soil pH is above 5.6.

Chloride (Cl^-)

Chloride is the most recent addition to the list of essential elements. Many people make the common mistake of confusing the plant nutrient chloride (Cl^-), with the toxic form chlorine (Cl). Chlorine is not the form that plants use. Chlorine exists either as a gas, or dissolved in water, such as bleach, and is not found in fertilizer. Although Chloride is classified as a micronutrient, plants may take-up as much Chloride as secondary elements such as Sulfur.

Function

Chloride is essential for many plant functions. Some of them are…

- It is essential (working in tandem with K^+) to the proper function of the plants stomatal openings, thus controlling internal water balance and tolerance to drought stress.
- It also functions in photosynthesis, specifically the water splitting system.
- It functions in cation balance and transport within the plant.
- Research has demonstrated that Cl diminishes the effects of fungal infections.
- It is speculated that Cl competes with nitrate uptake tending to promote the use of ammonium N. This may be a factor in its role in disease suppression, since high plant nitrates have been associated with increased disease severity.

Deficiency Symptoms

Wilting in conditions where that degree of stress is not normally expected. Also, restricted and highly branched root system, often with stubby tips. Some amount of general chlorosis has also been observed.

Factors Affecting Availability

Most soil Cl is highly soluble and is found predominantly dissolved in the soil water. Chloride is found in the soil as the Cl anion and highly mobile and may be leached from the soil profile. Where KCl is not applied regularly there is the potential for Cl shortages. Atmospheric Cl deposition tends to be rather high along coastal regions and decreases as you progress inland. Significant application rates or natural reserves of other nutrient anions (primarily NO_3 and SO_4, although B and Mo are also anions in their available forms) may reduce Cl availability. Conversely, high rates of Cl application can be antagonistic to other anion nutrients.

Toxicity Symptoms

Toxic symptoms are similar as is found with typical salt damage. Leaf margins are scorched and leaf drop is excessive. Leaf and leaflet size is reduced and may appear to be thickened. Overall plant growth is reduced. Chloride accumulation is higher in older tissue than in newly matured leaves.

Chloride Tolerance of Alfalfa	
Max soil Cl concentration threshold without yield loss	700 ppm*
Percent yield decrease/ppm Cl increase above threshold	0.02%
*Cl concentrations in saturated-soil extracts sampled in the root zone. Note: These data serve only as a guideline to relative tolerance. Absolute tolerances vary depending upon climate, soil conditions, and cultural practices. (*Chloride and Crop Production, Special Bulletin No. 2, Potash & Phosphate Institute)*	

Using Chloride in a Fertility Program

Chloride shortages are rare where muriate of potash fertilizer is used routinely. In areas where deficiencies are known to exist, 30 to 100 lb Cl/a per year will supply the needs of responsive crops. Response may be improved if the application is split

Some Common Fertilizer Products Containing Chloride		
Product	**Chemical Formula**	**Typical Chloride Content**
Sodium Chloride	$NaCl$	61%
Potassium Chloride	KCl	47%
Calcium Chloride	$CaCl_2$	64%

Soil and Plant Analyses do not routinely include Chloride analyses but are available upon request. Although interpretative data are limited, soil and plant analyses can be useful, especially where specific questions arise.

Recommended Practices for Top Alfalfa Yields

Like other crops, higher fertilizer rates alone are not enough to produce high alfalfa yields. Higher fertilizer rates can also be a significant cost. Following the best management practices both protects the fertilizer investment and insures better net income. Top yields and profits can only be achieved through the combined effects of optimizing all input and management practices. In addition to higher yields, alfalfa producers need high quality. Fortunately, sound management practices, coupled with good fertilizer programs can produce both higher yields and better quality.

The following points on non-nutrient production practices have been shown to be necessary to get top yields of high quality alfalfa.

Field Selection

Alfalfa is a deep-rooted perennial that needs a lot of water and high fertility. However, it can't stand waterlogged soil. An ideal situation would be a fertile soil where the roots can easily penetrate to several feet in depth. This requires a sub-soil with few physical or chemical restrictions. Deep rooting is critical to higher yields, because it greatly improves the crops ability to acquire the large amount of water and nutrients needed (see next section). Sub-soil rarely has desirable nutrient levels, but higher fertility sub-soils will generally improve the performance of alfalfa and most other crops. This may be one of those situations when a sub-soil sample could be useful.

Water

Various authorities have reported that alfalfa requires from 4 to 6 acre-inches of water per ton of yield. That's 40 to 60 acre-inches of water for a 10 ton yield. This water can come from any combination of stored water, rainfall, and irrigation. However, soils that are well-drained (see previous section) may not be able to store much water. In these situations, or where the annual rainfall is simply too low, producers interested in producing high yields should evaluate the potential for installing irrigation. Water during the late-summer and fall months is especially critical for fall seeded alfalfa. Good germination and rapid fall growth are critical to good plant stands in the spring, and this is one of the keys to higher yields.

Seed Source

Take the time to select varieties that have the potential to produce high yields. Many seed companies have varieties capable of producing exceptional yields. Check local performance trials and respected authorities to make this decision and be sure to properly inoculate your seed.

Two studies comparing top alfalfa varieties to Buffalo variety in Kentucky and to Vernal in Wisconsin found the economic differences in the accompanying tables. As the data shows, top varieties typically cost more per pound and per acre.

Seed Cost per Pound and per Acre for Average of Top Varieties, Buffalo, and Vernal

Variety	Avg Seed Cost	Seed Cost/a at 15 lb/ac Rate	Seed Cost/a/yr	
	$/lb	$/ac	7 yr stand	3 yr stand
Avg. of Top Varieties	$3.50	$52.50	$7.50	$17.50
Buffalo or Vernal	$1.00	$15.00	$2.14	$5.00
Difference	$2.50	$37.50	$5.36	$12.50

Economic Return on Investing in Improved Alfalfa Varieties with Varying Hay Prices.

Dollars per Ton	Gross Return/acre*	
	Bowling Green	Arlington
60	$397	$204
80	$530	$272
100	$662	$340
120	$794	$408
140	$929	$476

* 6.6 T/ac increase over 7 years and Bowling Green, Ky.; 3.4 T/ac increase over 3 years at Arlington, Wis.

However, the better yields and longer-lasting stands provided by the better varieties result in more income per acre. The authors calculated that, depending on the value of the hay, the two trials show that the **top varieties increases profits from $167 to over $800 per acre over the life of the stand.**

Seeding Rate

Recommendations are around 12-20 lb. seed/acre, depending on the source of information. Recommended seeding rates for some flood-irrigated systems in California can range as high as 40-50 lb. /acre, due to loss of seed during the “watering-up” of the field after seeding. The record-breaking irrigated alfalfa produced by the University of Arizona, listed earlier, was planted at a rate of 20 lb. /acre. Many high, non-irrigated yields have been achieved with seeding rates of around 15 lb/ac.

Plant Population

You can’t have high yields without enough healthy, vigorous plants in the field. Most authorities recommend guidelines similar to the following.

Stand Density

Age of Crop	Plants/ft^2
Seeding year	20-50
1st year	12-25
2nd year	8-12
3rd year	5+

Stem Count (at 4" to 6" tall alfalfa)

Stem count/ft^2	Suggested practice
<42	Rotate field out of alfalfa
40-55	Yield reduce, but still economical
55+	Maximum production

Insect Control

Alfalfa can be damaged by many insects (consult local extension publications) and high yields require that all insects be limited to low population levels. However, only potato leafhopper data is listed here. This is because leafhopper damage often goes unnoticed until after the damage has occurred. Without good monitoring, many growers are surprised by the amount of tonnage lost to this insect before visual damage is discovered. As you might expect, authorities differ on when and how to treat for potato leaf hoppers. The following economic thresholds are typical. Options for limiting losses to many insects include pesticides and early cutting. However, early cutting may limit yields and, over time, weaken the plant stand. In some cases, earlier cutting can also provide slightly higher levels of some quality factors. (see later section). Also keep in mind that where other pressures exist in the same field, economic thresholds for each individual insect or weed may be lower.

Potato Leafhopper Action Thresholds for 10 Sweeps

	Alfalfa Tolerance for Stress*		
Stem Height	**Low**	**Normal**	**High**
	Adult + Nymph Avg/10 sweeps		
0-3"	n/a	2	n/a
6"	3	6	9
8"	4	8	12
10"	5	10	15
12"	6	12	18
14"	7	14	21
16"	8	16	24
18"	9	18	27
20+"	10	20	30

*Low: Alfalfa under environmental stress and very susceptible to PLH injury

High: Alfalfa exhibiting vigorous growth and capable of tolerating some injury

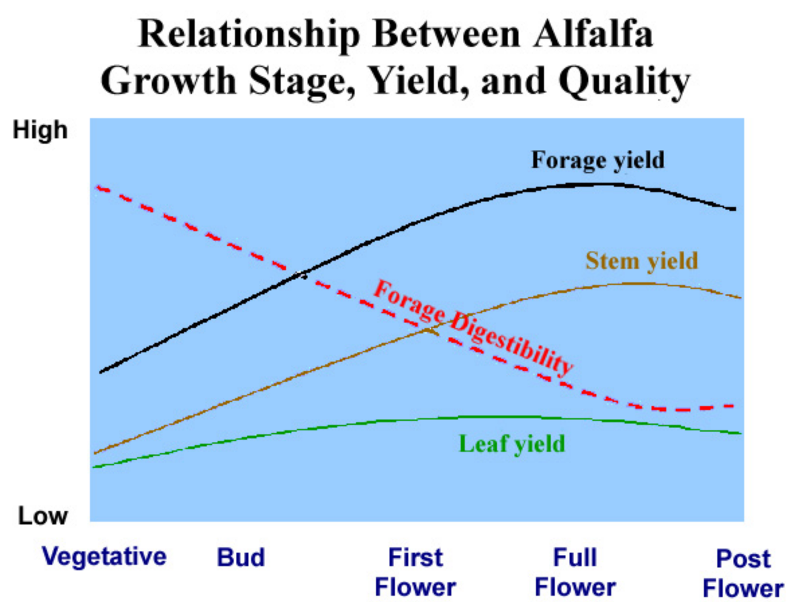
Harvest Management

It would take a separate paper to present all of the needed and available information on proper alfalfa cutting management... and after all was written, the grower would still be left with some difficult in-field decisions to make. Therefore, we have included some of the more significant items from various sources. The point is simply to illustrate the general effects of different cutting strategies on yield, quality, and stand persistence.

The basic relationships in different harvest strategies is that later cutting (except for the last fall cutting) tends to improve yield and stand persistence at the expense of feed quality, while earlier cutting tends to favor improved quality, but reduce yield and stand persistence. The following data illustrates the effect of cutting stages on these factors.

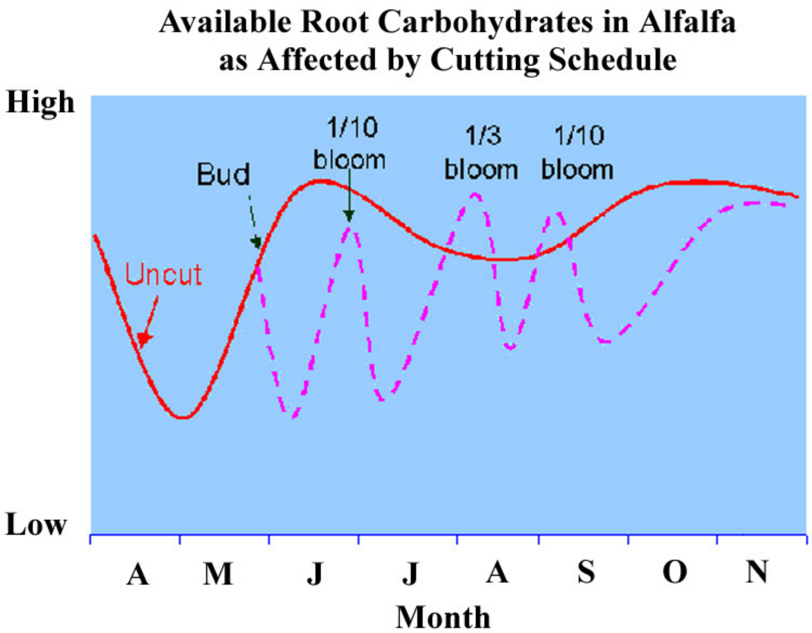
This table is an illustration of the changes in alfalfa quality as affected by the stage of maturity at cutting					
Growth Stage	**CP**	**ADF**	**NDF**	**RFV**	**Pct. Chg. In RFV vs. E. Bloom**
Late veg.	23	28	38	164	+13.8
Bud	20	29	40	154	+6.9
E. Bloom	18	31	42	144	0
Bloom	17	35	46	125	-13.2
F. Bloom	15	37	50	112	-22.2

From the above data, it would seem that early (and therefore frequent) harvests would be best to achieve high quality feed. However, this is a trade-off. This trade-off takes the general relationship shown in the chart below.



Alfalfa is a perennial plant that stores carbohydrates (energy reserves) in the roots and crown. These reserves are used by the plant to quickly produce new vegetative growth after cutting. Even an aggressive cutting schedule, when properly done, does not hurt root reserves by the end of the season. However, early and frequent cutting causes the plants to draw down these reserves, making them less able to withstand other stresses, including winter survival. Of course, as the root reserves are diminished, the amount and/or speed of regrowth after each cutting may be reduced.

In the chart below, earlier or more frequent cutting would lower the peaks in the dashed line, resulting in a gradual reduction in root reserves going into the winter. This often results in thinner stands in succeeding seasons and accompanying lower yields. As the stand thins out over the years, grass and weeds become established, both lowering the quality of the forage and providing competition for water and nutrients.



Therefore, frequent early cutting can reduce future yields as well as the persistence of the stand. The optimum harvest time is almost always a compromise between yield and quality.

Notice in this chart that the mid-summer cutting is shown as being at 1/3 bloom. A mid-to-late summer cutting is often lower yielding and if the forage is not urgently needed, this can be an effective strategy for improving alfalfa root reserves. Of course, cutting this late will tend to be of lower quality so adjustments to feed rations may need to be made. The offsetting benefit is a more persistent crop of alfalfa.

Dairy farmers may have more difficult decisions than most. Each dairy producer's situation will be different, but they may find that early harvests, which result in somewhat lower alfalfa yields and less persistent stands, could result in offsetting increases in milk production and profits. A study posted on the Pioneer Seeds web-site listed results from one of their studies into the effect of harvest intervals on alfalfa quality and milk production. We extended their results to include projected pounds of milk production per acre.

Effect of Harvest Interval on Relative Feed Value (RFV), Crude Protein (CP), and projected milk production

Harvest Interval	RFV	CP%	Avg. Yield (T/a)	Projected Lb Milk per Ton of Alfalfa	Lb. Milk per Acre
28	166	24.9	5.8	1303	7557
31	163	24.6	6.1	1293	7887
34	157	23.9	5.9	1284	7576
37	155	23.8	6.3	1277	8045
LSD (0.05)	1.6	0.18	na	3.9	na