Alfalfa Fertility Requirements

by

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Developing a perspective for the fertility requirements of alfalfa begins with the knowledge and appreciation of the quantity of plant nutrients removed in the hay crop which is harvested (Table 1). Adequate supplies of the essential plant nutrients are necessary for maintaining productive alfalfa yields. A brief review of how these nutrients are obtained by alfalfa will lead to areas of consideration where fertilizer additions are required.

Large quantities of nitrogen are utilized to produce high yields and the desired protein levels. The major source is nitrogen from the atmosphere as fixation occurs through the mutually beneficial relationship between the alfalfa plant and the nitrogen fixing rhizobia bacteria located in the nodules on the roots. In so far as the quantity taken up by alfalfa is concerned, potassium and calcium are next in their relative amounts removed by alfalfa. In most situations the potassium supplied by soils is quite adequate to insure necessary quantities for maximum alfalfa yield production. However, in some sandy soils and perhaps others, this may not be the case and response to added potassium can be obtained. Calcium likewise is adequately supplied by most soils. Nutrient supplies of calcium very seldom limit alfalfa yields unless soil pH levels drop somewhat below 5.0 throughout a major portion of the soil profile.

Although a smaller quantity of phosphorus is taken up by alfalfa, perhaps it is the nutrient which most often limits alfalfa hay production. A number of soil factors including pH, temperature, degree of compaction, rooting depth, water management, and chemistry of the soil influence the supply of

TABLE 1. Nutrient quantities contained in 8 tons of alfalfa hay.

Nutrient	Chemical Symbol	Pounds
Nitrogen	N	480
Phosphorus	P_2O_5 (P)	94 (42)
Potassium	K_2O (K)	350 (290)
Calcium	Ca	256
Magnesium	Mg	53
Sulfur	S	32
Iron	Fe	3
Manganese	Mn	2
Zinc	Zn	0.3
Copper	Cu	0.2
Chlorine	Cl	2
Molybdenum	Mo	.02
Boron	B	.5

phosphorus available to the plant. A more thorough discussion of this topic appears later in this article. Sulfur is another nutrient which is often responsible for increasing yields of alfalfa. This is most often true in the intermountain area of Northern California. The degree to which micronutrients such as boron, molybdenum, and perhaps zinc affect alfalfa yields is rather small. Several locations within the intermountain area are known to have marginally low levels of boron and molybdenum in plant tissue samples of alfalfa. Maintaining adequate levels of boron becomes very important in the production of seed crops, particularly alfalfa.

Factors affecting the economic returns from fertilizing alfalfa

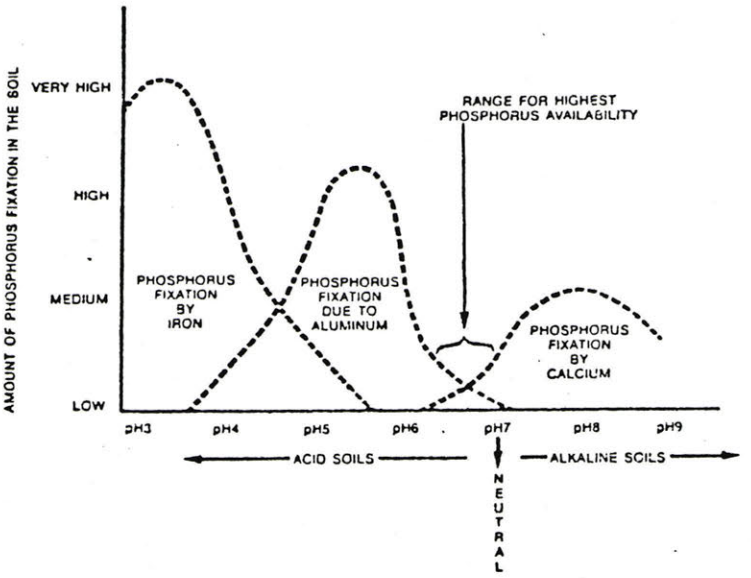
Nitrogen One of the major economic considerations involved in fertilizing alfalfa is the addition of nitrogen. Some growers have felt that nitrogen applications to augment the amount supplied by rhizobia bacteria can be beneficial in the production of alfalfa. Generally it is more beneficial and economically feasible to insure that the plants are adequately inoculated with effective strains of bacteria and growing conditions provide for maximum productivity of the rhizobia. Irrigation practices which supply adequate moisture levels and minimize flooding for extended periods of time are necessary for effective rhizobial activity. Compacted soils which restrict root growth and limit oxygen diffusion into the soil may reduce fixation capacity. Acid soils having a pH below 6.0 may inhibit the productivity of the symbiotic plant-bacterial relationship. Additions of nitrogen can offset some of the effect that these adverse growing conditions exert on the growth of alfalfa but an even greater potential yield may be realized if these limitations to plant growth are alleviated.

The often asked question of whether or not applied nitrogen could improve yields prompted the initiation of an experiment wherein large rates of nitrogen were applied. Soil characteristics at the site were as follows: pH 5.5 to 5.8, bicarbonate-P 15.4 to 28 ppm, exchangeable-K 190 to 220 ppm and Hot Nitric-K 340 to 400 ppm. The trial arrangement in the field has the non-inoculated treatments located about 120 feet away from the inoculated treatments. Table 2 gives the list of applied treatments, the 1982 to 1984 and three year average yields in tons DM/A. It should be pointed out that yields have been considerably higher in the non-inoculated area than in the inoculated area. Careful examination of plants has revealed that both areas have good inoculation and that soil-moisture regimes are more responsible for yield differences. A trend appears in all years for the alfalfa yields to increase

with additions of phosphorus, potassium, lime and nitrogen. In the non-inoculated area the 1200 lbs N/A treatment indicates a somewhat lower yield whereas in the inoculated area the 600 and 1200 lbs N/A treatments have slightly higher yields than the 300 and 900 lbs N/A treatments. Both the ammonium nitrate and calcium nitrate sources of nitrogen applied at the 600 lb N/A rate resulted in very similar yields.

Phosphorus As was indicated earlier phosphorus is perhaps the plant nutrient which is more frequently limiting maximum production of alfalfa. To gain some appreciation as to why this might be the case, let us discuss briefly the soil reactions which limit the quantity of phosphorus in soil solution and thus the amount available for plant uptake. Figure 1 illustrates the degree to which iron, aluminum, and calcium render the phosphorus unavailable for uptake by the plant. In acid soils, iron and aluminum precipitate or form insoluble salts in the soil as they react with the phosphorus dissolved in the water phase around the soil particles. When the

Figure 1. Phosphorus fixation in the soil.



pH of the soil increases above 7, calcium is largely responsible for the precipitation or formation of insoluble salts. As the figure illustrates, the pH range of 6-7 is the range in which the highest availability of phosphorus for plant uptake exists. Because large additions of soluble phosphorus become unavailable so quickly in the soil, annual or every other year applications are required to insure an adequate supply is available to the plant. Thus, economics usually favor an application of phosphorus be incorporated before planting and follow-up applications be made approximately every two years.

Phosphorus Placement The question often arises as to the value of incorporated phosphorus treatments as compared to surface broadcast applications. Table 3 gives the alfalfa yields following the application of Treble Superphosphate (0-45-0) broadcast on the surface or injected 6 inches deep with a 10 inch lateral spacing. The three-harvest total for 1976 indicated a trend of higher yields with increasing rates of phosphate. However, there is no difference between the injected and broadcast treatments for the same rate of phosphorus application. The total of 7 harvests in 1977 indicates a significant response to applied phosphorus. It would appear as if there is a greater response to injected than broadcast phosphorus, however the difference of 0.3 tons between the broadcast and injected controls remains nearly the same between the yields of similar phosphorus rates. The economic evaluation in Table 3 would indicate that injected phosphorus has little, if any, advantage over broadcast application. In another location shanking treatments with and without phosphorus in an established stand indicated a reduction in yield the first harvest after application. By the third harvest after application, the shanked-in phosphorus treatment gave the same yield as the surface broadcast treatment. Meanwhile, the broadcast application resulted in a sizeable yield increase over the control for both the second and third harvest.

TABLE 3. Alfalfa yields following the application of treble superphosphate and an economic evaluation of responses. (Imperial County, Robert W. Hagemann)

Placement	Phosphorus Applied (lbs P_2O_5/A)	Yield, Tons DM/A 1976(3)[1/]	1977(7)[1/]	Total	Value[2/] ($/A)	Relative Value ($/A)	Costs[3/] ($/A)	Net Profit ($/A)
Injected	0	3.25	7.78	11.03	992.70	25.20	18.00	7.20
Injected	100	3.47	8.43	11.90	1071.00	103.50	46.00	57.50
Injected	300	3.41	9.14	12.55	1129.50	162.00	102.00	60.00
Broadcast	0	3.26	7.49	10.75	967.50	0	0	0
Broadcast	100	3.45	8.17	11.62	1045.80	78.30	33.00	45.30
Broadcast	300	3.59	8.85	12.44	1119.60	152.10	89.00	63.10

1/ Number of harvests included in each year total

2/ Alfalfa hay value-$90./ton

3/ Injection, $18.00/A; Broadcast, $5.00/A; Fertilizer, $.28/lbs P_2O_5

An experiment in Siskiyou County with Farm Advisor Roger Benton indicated no particular advantage with phosphorus injected over that broadcast on the surface at the 80 or 160 lbs P_2O_5/A rates when the applications were made in early April and three harvests taken throughout the year. From these and other trials it would seem that the slight advantage resulting from injected phosphorus as compared to surface broadcast would seldom result in agronomically significant yield increases or even marginal economic benefit considering the greater cost of injected applications and some damage to alfalfa crowns.

Many are familiar with the rapid and dramatic early seedling growth response when phosphorus or combinations of nitrogen and phosphorus are placed near the seed, particularly for those crops growing during periods when soil temperatures are low. Alfalfa response to phosphorus can be very significant

and the increase in yield usually accrues over a longer period of time, perhaps as much as 3-4 years. This can be illustrated by the data presented in Table 4. Following the application of phosphorus in January, the yield

TABLE 4. Alfalfa yield response to surface applied treble superphosphate and potassium chloride. (Lassen County, Carl Rimbey and Lester Allen)

Fertilizer Applied in January of			Yield, Tons DM/A (3 harvests/year)					
1974	1976							
P_2O_5 (lbs/A)	P_2O_5 (lbs/A)	K_2O (lbs/A)	1974	1975	1976	1977	Totals	Yield Increase
0	0		4.95	4.77	3.64	2.43	15.79	
100	0		5.41	6.07	5.05	3.57	20.20	4.31[1/]
100	100		-	-	5.46	3.88	9.34	.72[2/]
100	100	100	-	-	5.58	4.00	9.58	.24[3/]

1/ Yield increase over control during 1974-1977

2/ Yield increase over first phosphorus application during 1976-1977

3/ Yield increase over phosphorus treatments during 1976-1977

difference was approximately 0.5 ton/A for the 1974 season. In subsequent years, with no further application of phosphorus, yield response was 1.3, 1.4 and 1.2 ton/A for 1975, 1976 and 1977 respectively. The four year total yield increase following the single 100 lbs P_2O_5/A application of phosphorus was 4.3 tons/A (Table 4). The original plots were split in January 1976 with part receiving phosphorus and the other part none. Yields following the second 100 lbs/A application resulted in 0.4 ton/A over the initial phosphorus treatment during 1976 and 0.3 ton/A in 1977. On another portion of the split plot potassium and phosphorus were applied resulting in a slight trend for a yield response during both years. One of the conclusions that can be drawn from

this trial is that surface applied phosphorus can be extremely effective in increasing alfalfa yields when the soil does not supply an adequate amount. Unfortunately a comparison between injected and surface broadcast treatments was not included in this trial. Table 5 presents an economic evaluation of the alfalfa response to surface applied phosphorus and potassium. The yield increase over the 4 year period resulted in a $312.80 return per acre whereas the second 100 lbs P_2O_5/A returned a profit of $25.60 per acre over the 2 year period.

Another observation which should be mentioned is the marked effect of phosphorus and potassium application on stand density. The loss of stand became strikingly apparent during 1976 and 1977 when the difference between no phosphorus treatments where few plants remained and multiple applications of phosphorus where a dense stand existed. There was a considerable intrusion by tall fescue in the plots receiving no phosphorus. From the experimental results presented it becomes apparent that whenever a phosphorus response can be expected from alfalfa, there may be a very small advantage for injected placement as compared to surface broadcast application to established stands. There would definitely be a much earlier response in the case of a new seeding where the phosphorus is incorporated into the surface 6-8 inches prior to establishment. In the case where phosphorus is quite deficient, the new seeding would show a much faster response to phosphorus or a nitrogen-phosphorus combination placed very near the seed at planting time in addition to that incorporated into the top 6-8 inches. This "starter" fertilizer response often results in the alfalfa competing more favorably against weeds and assists in bringing it up to full production more rapidly.

TABLE 5. An economic evaluation of alfalfa response to surface applied phosphorus and potassium. (Lassen County, Carl Rimbey and Lester Allen)

Fertilizer Applied in January of			Total Yield			
1974	1976		Increase	Value[1/]	Costs[1/]	Profit
P_2O_5 (lbs/A)	P_2O_5 (lbs/A)	K_2O (lbs/A)	(tons/A)	($/A)	($/A)	($/A)
100	0	0	4.31	344.80	32.00	312.80
100	100	0	.72	57.60	32.00	25.60
100	100	100	.24	19.20	18.00	1.20

1/ Alfalfa hay value - $80./ton

2/ Broadcast application - $4.00/A; Phosphorus - $.28/lb P_2O_5; Potassium - $.18/lb K_2O

Sulfur Another nutrient which often limits production in the intermountain areas of Northern California is sulfur. Sulfur availability to the plant is influenced by climatic conditions which effect the soil environment and influence microbial activity. Specifically, the bacterial oxidation of sulfur forms to the sulfate sulfur (SO_4-S) needed by plants. Temporary sulfur deficiency in a number of soils may exist in the spring when wet, perhaps even water-logged soil conditions, along with cool temperatures limit the availability of sulfur and alfalfa growth is reduced. Generally it is not economically feasible to apply sulfur to correct this problem because of the short time period it limits the growth of alfalfa and the need for application of a sulfate source just prior to its occurrence in early spring. Higher rates of sulfur applied to the soil may or may not correct this kind of deficiency. Of the factors that effect the availability of sulfur to alfalfa, whether it is in the elemental or sulfate form is the most important. Research in Shasta County with Farm Advisor Dan Marcum indicates the kind of

response that can be expected from early season applications on the soil surface of gypsum and elemental sulfur to existing alfalfa stands. Table 6 shows the very rapid response which can be expected from a sulfate form of sulfur such as gypsum. As the fertilizer treatments were applied on February 12, it becomes apparent that response can normally not be expected from elemental forms until later on in the summer as is indicated by the July 10 harvest when the 50 and 100 lb rates began to show a response. Undoubtedly the most important factor in determining the rate of response from elemental sulfur is the particle size. The smaller the particle size the more rapid is the bacterial oxidation to the sulfate form. The elemental sulfur used in this trial had 60% by weight in the size range of less than 2 mm but larger than 1 mm and 40% in the 1 mm or smaller size. Another important factor regarding sulfate sulfur is that it can be leached from the root zone. More frequent applications are necessary to maintain adequate supplies of sulfur for alfalfa than when elemental forms are applied. This is illustrated by the alfalfa yield data from the same experiment for 1980 which is given in Table 7. In general, the yields for the three rates of gypsum are somewhat lower than the three rates of elemental sulfur. The trend for lower yields after the first year of gypsum application has resulted in a recommendation that gypsum be applied annually. The use of larger amounts of elemental sulfur provides an adequate supply of the nutrient for alfalfa for several years. In areas where sulfur is known to be deficient, a program such as the following can be used to supply adequate amounts for maximum alfalfa production; the incorporation of 200-300 lbs/A elemental sulfur into the soil prior to planting along with the application of the sulfate form in a starter fertilizer such as 16-20-0 or 0-25-0 provides readily available sulfur for early growth and a 5-7 year supply for continued growth.