THE ECONOMICS OF FERTILIZING ALFALFA IN CALIFORNIA

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Looking back over the past year, the economic picture for alfalfa production has been quite favorable. Stronger prices for alfalfa hay certainly provide a good setting for a discussion of the economics of fertilizing alfalfa. Not that this should be the only criteria, as fertilization is most frequently a valuable input even when prices are somewhat depressed.

As one evaluates more carefully the fertilizer cost inputs into alfalfa production, a look at the nutrients taken up by the crop becomes quite useful (Table 1). More nitrogen is contained in the crop than any other nutrient. The major source being 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 California soils is quite adequate to insure necessary quantities for maximum alfalfa yield production. However, in some sandy soils this may not be the case and response to potassium can be obtained. Calcium likewise is adequately supplied by most all soils in California. Nutrient supplies of calcium very seldom limit alfalfa yields unless soil pH levels drop somewhat below 5.5 throughout a major portion of the soil profile.

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	

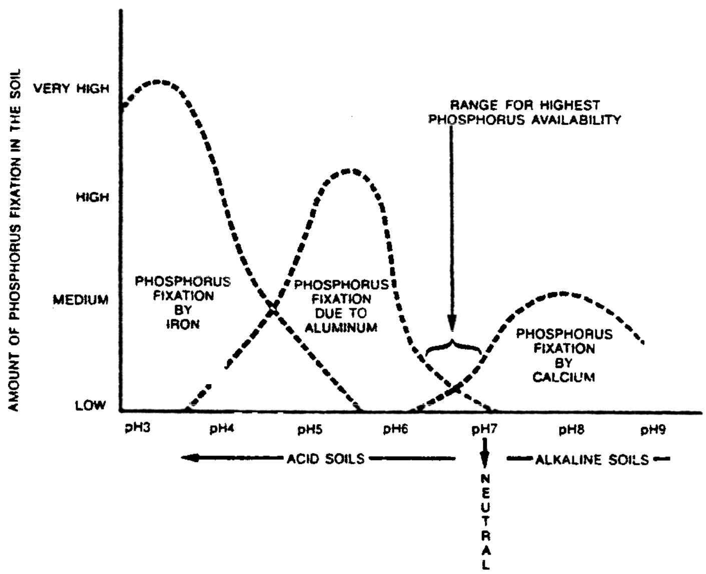
Although a smaller quantity of phosphorus is taken up by alfalfa, perhaps it is the nutrient which most often limits alfalfa hay production. A number of soil factors including pH, temperature, degree of compaction, rooting depth, water management, and chemistry of the soil influence the supply of phosphorus 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 inter-mountain area of Northern California. The degree to which micro-nutrients such as boron, molybdenum, and perhaps zinc affect alfalfa yields is somewhat difficult to determine. Several locations within the inter-mountain area have shown marginally low levels of boron and molybdenum in plant tissue samples of 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 provides for their maximum productivity. 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 5.5-6.0 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 were alleviated.

Phosphorus. As was indicated earlier phosphorus is perhaps the plant nutrient which is most 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

Figure 1. Phosphorus fixation in the soil.



around the soil particles. When the pH of the soil increases above 7 as might be particularly true in many of our San Joaquin Valley soils where the pH is 7.5 or higher, 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, frequent 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 2 gives the alfalfa yields following the application of Treble Superphosphate (0-45-0) broadcast on the surface and injected 6 inches deep with a 10 inch lateral spacing. The three-harvest total for 1976 indicates 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 similar response to applied phosphorus. It would appear as if there is a response to injected phosphorus, however when the broadcast and injected controls are compared, the difference of 0.3 ton with no phosphorus applied remains nearly the same between the yields of similar phosphorus rates. In another location shanking with and without phosphorus in an established stand indicated a reduction in yield the first harvest after application. By the third

TABLE 2. Alfalfa Yields Following the Application of Treble Superphosphate. (Imperial County, Robert W. Hagemann)

Treatment	Phosphorus Applied lbs P_2O_5/A	Yield, Tons DM/A	
		1976(3)*	1977(7)*
1. Injected	0	3.25	7.78ab**
2. Injected	100	3.47	8.43 bcd
3. Injected	300	3.41	9.14 d
4. Broadcast	0	3.26	7.49a
5. Broadcast	100	3.45	8.17abc
6. Broadcast	300	3.59	8.85 cd

* Number of harvests included in each year total.

** Yields followed by the same letter are not significantly different.

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 harvests.

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 and 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.

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. Alfalfa response to phosphorus can be very significant but 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 3. Following the application of phosphorus in January, the yield 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 original plots were split in January 1976 with part receiving phosphorus and the other part none. Yields from the reapplication 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. 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 along with potassium where a dense stand free of intruding tall fescue existed. From the experimental results presented it becomes

TABLE 3 Alfalfa Yield Response to Surface Applied Treble Superphosphate. (Lassen County, Carl Rimbey and Leser 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
0	0		4.95	4.77	3.64	2.43
100	0		5.41	6.07	5.05	3.57
100	100				5.46	3.88
100	100	100			5.58	4.00

apparent that whenever a phosphorus response can be expected from alfalfa, there may be a very little 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 up to full production more rapidly.

Sulfur. Another nutrient which often limits production in the inter-mountain 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 waterlogged 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. Current 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 4 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

TABLE 4. Alfalfa Yields in 1979 Following the Application of Sulfur Treatments on February 12, 1979.

	Treatment		Yield, Tons DM/A				
			5/23	7/10	8/13	9/28	Total
	Control		0.68	1.22	1.19	.77	3.86
2.	Gypsum	25 lbs S/A	2.16	2.84	1.93	1.26	8.19
3.	Gypsum	50 lbs S/A	2.35	3.21	2.07	1.54	9.17
4.	Gypsum	100 lbs S/A	2.15	2.87	.78	1.59	8.39
5	Elemental sulfur	25 lbs S/A	.76	.27	.30	.90	4.23
	Elemental sulfur	50 lbs S/A	.83	.45	.43	1.06	4.77
	Elemental sulfur	100 lbs S/A	.85	.77	.60	1.35	5.57

when elemental forms are applied. In areas where sulfur is known to be deficient a program as follows 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 0-20-0 provides readily available sulfur for early growth and a 5-7 year supply for continued growth.

Boron. Deficiencies have been detected in a number of locations in the inter-mountain areas of Northern California. The need for rather small amounts of 2-4 lbs/A of actual boron suggests that applications be made by aircraft or by means of sprayer equipment. Boron deficiency is of extreme economic importance when it occurs in alfalfa seed production.

Molybdenum. Applications of molybdenum may be necessary in certain portions of the inter-mountain areas of Northern California. The most efficient application of molybdenum is by seed treatment wherein sodium molybdate is added to the inoculant at the time of seeding. Broadcast applications may result in much higher rates being applied in certain areas of the field which increase the likelihood of toxicities of molybdenum for animals. This can become a problem where low levels of copper may be associated with the higher levels of molybdenum in the forage.

Diagnosing the nutritional status of alfalfa

Soil Testing. The most helpful tool in determining the fertilization needs before the establishment of alfalfa would be the soil test. Obtaining a representative soil sample of the field to be seeded and having a phosphorus determination made to assess whether the levels are below 5 ppm will indicate a likelihood for phosphorus response. If the level is greater than 10 ppm a lower likelihood for phosphorus response would be expected. Potassium determinations on soils samples are also quite helpful in diagnosing responses. Levels below 40 to 50 ppm would indicate a likelihood for potassium response whereas levels greater than 100 would usually not result in a response. If levels are below 100 ppm when the ammonium acetate extract is used, it is desirable to confirm the need for potassium application by utilizing the hot nitric acid. Soil test levels below 200 ppm would indicate that a potassium response is likely. Values greater than 300 ppm would normally not result in a response. Soil tests for sulfur and boron are much less valuable in determining the needs for these two nutrients for alfalfa production.

Plant Tissue Analysis. A much more desirable tool for diagnosing the nutritional status of alfalfa is through the use of analysis of plant tissue. Careful interpretation of the results along with a consideration of what soil tests indicate will provide direction to a sound fertility program. One important item should be kept uppermost in the evaluation of a plant tissue analysis. The single plant nutrient most deficient is responsible for the reduced growth or a decrease in yield. That is to say, if one nutrient is deficient and is responsible for surpressing the potential yields of alfalfa, this nutrient must be supplied before an evaluation of the other nutrient concentrations is considered. It has often been observed that when surpressed level of one nutrient occurs, either an elevated concentration or a somewhat surpressed concentration of several other nutrients may take place. Table 5 gives the range in nutrient concentrations for specific parts of plant samples taken when regrowth from the crown is from 1 to 2 inches in length (about 1/10 bloom).

TABLE 5. Nutrient Concentrations in Alfalfa at Different Response Levels

	Midstems		Leaves	Top 1/3 of Plant	
Response Category	Total K	PO_4-P	SO_4-S	Total Mo	Total B
	(%)	(ppm)	(ppm)	(ppm)	(ppm)
Deficient	.40-.65	300- 500	<80	<.3	<15
Critical	.65-.80	500- 800	80-150	.3-.9	
Adequate	.80-1.5	800-1500	150-500	1-5	20-40
High	1.5+	1500+	500+	5-10*	

Forage containing more than 10 ppm of Mo may produce "Molybdenosis" in ruminant animals.

** Boron concentrations in alfalfa greater than 200 ppm are associated with reduced growth and vigor.

Plant Symptoms. A third means of diagnosing deficiencies is by observation of plant nutrient deficiency symptoms. However, a word of caution might be that positive identification is often difficult for the experienced observer, particularly if an extremely low level of one nutrient has brought about other nutrient imbalances which have altered the usual symptoms. This may also be the case in the event that insect or disease damage has resulted in symptoms which might be attributed to a limited nutrient supply.

Fertilized and Unfertilized Strips. The fourth and perhaps most valuable method of evaluating economic levels of application to individual grower fields of alfalfa is by the use of different rates of fertilizer materials followed by careful yield determinations from these check strips throughout the field. A word of caution however, would be that these alternating strips of different rates along with a control where no fertilizer is applied should be located several places in the field and careful yield determinations be made to document the yield advantage that is gained by a particular fertilizer treatment. Comparing this field against that field, even though they may have very similar cropping histories can be very misleading because of water management, varieties, insect control or numerous other management and cultural factors which contribute to yield differences.