MAXIMIZING FERTILIZER EFFICIENCY THROUGH TISSUE TESTING AND IMPROVED APPLICATION METHODS

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ABSTRACT

Farmers worldwide are keenly aware of the dramatic increase in fertilizer prices over the last couple of years. This provides even greater incentive to maximize fertilizer efficiency to ensure an economic return. Growers should calculate the minimum yield level needed to equal the cost of fertilizer application at varying application rates, hay prices, and phosphorus fertilizer prices, and estimate the probability of exceeding that level. Banded versus broadcast applications of phosphorus were evaluated as a means of increasing fertilizer application efficiency. A yield response to fertilizer was observed at some sites, but application method (banded vs. broadcast) had no effect on yield at the study locations. Current economic conditions and high fertilizer prices make it imperative that growers have an accurate assessment of the nutritional status of their fields before fertilizing. Both soil tests and plant tissue tests are valuable diagnostic tools, however, plant tissue tests provide a better reflection of plant uptake. Recent research indicated that cored-bale samples could be used successfully in lieu of fractionated stem samples. Further evaluation is needed to determine how to standardize plant tissue testing based upon of plant maturity, and time of year for improved accuracy.

Key Words: Alfalfa, *Medicago sativa*, nutrient requirements, fertilizer rate, soil testing, phosphorus, economics

INTRODUCTION

Adequate plant nutrition is paramount to achieving high alfalfa yield. In addition, nutrient management is an important environmental issue and cost for agriculture. Fertilizer costs are a major concern for alfalfa producers and cause growers to question the profitability of applying fertilizer. The increase in fertilizer costs over the last few years—especially the last two years—has been nothing short of phenomenal. Figure 1 shows typical retail prices for the most popular

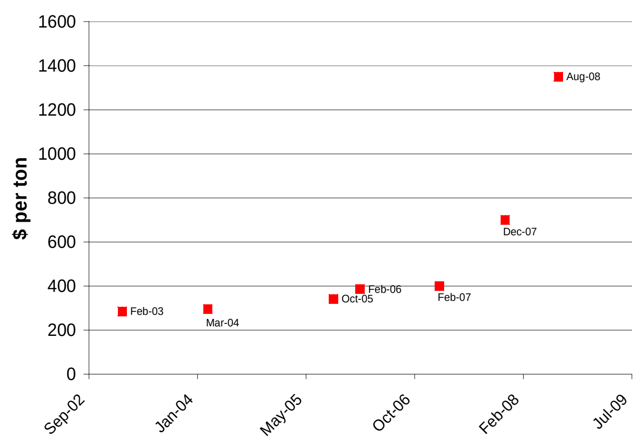

Figure 1. Typical retail price for 11-52-0 over the past 6 years.

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phosphorus fertilizer in the West (11-52-0) over the last six years. 11-52-00 prices had been relatively stable for several years. Then there was a gradual increase from slightly less than $300 per ton to about $400 per ton by the beginning of 2007. But by the end of 2007 the price had soared to over $700 per ton. The agricultural industry was stunned by this price increase but the price continued to climb to nearly double that value in 2008. Other fertilizer sources and nutrients experienced similar increases in price.

What does this radical price increase mean for the alfalfa industry? Alfalfa uses rather large quantities of phosphorus and, in some production areas, other nutrients as well. Thus, high fertilizer prices have potentially a large impact on alfalfa growers. Fortunately, alfalfa hay prices for most of this year were also at record high levels but profit margins were impacted by increases in other input costs in addition to fertilizer, particularly fuel. Growers must carefully scrutinize the potential benefits of fertilization to ascertain the economics of fertilizing for this coming season. In these volatile economic times, it is difficult to predict what will be the price of fertilizer in the coming year as well as what will happen with the alfalfa market. However, a logical first step to help answer the question whether it will be profitable or not to fertilize alfalfa with such high-priced fertilizer is to determine the yield increase that would be required to pay for the cost of fertilizer. We will consider the cost of 11-52-0 since phosphorus is by far the primary supplemental nutrient needed for alfalfa production in California. However, a similar type of analysis could be performed for other nutrients as well.

What yield response is needed to justify fertilizer applications? The yield increase needed to cover the cost of the fertilizer (and the application) for varying application rates, alfalfa hay prices, and costs for 11-52-0 are shown in Figures 2 and 3.

At high hay prices, a smaller yield benefit is required to justify fertilizer applications (Figure 2). Similarly, at high fertilizer prices, a greater yield benefit is required to justify applications. At the $1200/t cost we've seen this summer, greater than 0.6 ton/acre alfalfa yield is required to justify fertilizer applications.

These prices for the hay need to be discounted slightly for increased harvest costs associated with higher yields. For example, a yield increase of a ton has a concomitant increase in harvest costs. Thus, the anticipated yield increase should surpass the values shown in the figures.

Back when 11-52-0 was $400 per ton, a yield increase of only slightly over 0.2 tons per season was needed if the hay price (minus increased harvest costs) was $200 per ton. However, at an 11-52-0 price of

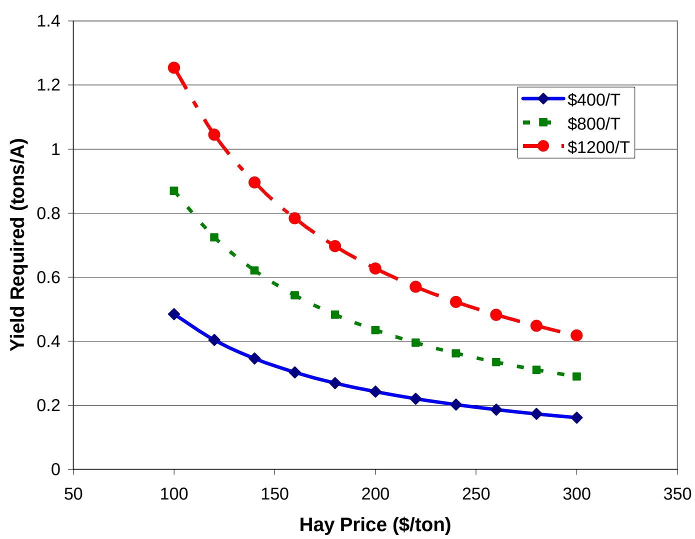

Figure 2. Seasonal yield increase needed to cover the cost of a 100 lb/acre P_2O_5 application at three price levels of 11-52-0 and various alfalfa hay prices. Fertilization application cost of $10 /A assumed.

$1200 per ton a yield increase exceeding 0.6 tons per acre is needed to break even.

Figure 3 is similar to Figure 2 but it shows the yield increase needed to cover fertilizer and application cost at different phosphorus application rates. The assumed hay price used in this figure is $200 per ton (again, not accounting for increased harvest costs). Using this figure, it is apparent that approximately a 0.33 ton per acre yield increase is needed to break even with a 50 pound application of P_2O_5 per acre at an 11-52-0 price of $1200 per ton. However, a yield increase of at least 0.9 tons is needed to break even with a 150 pound per acre P_2O_5 application.

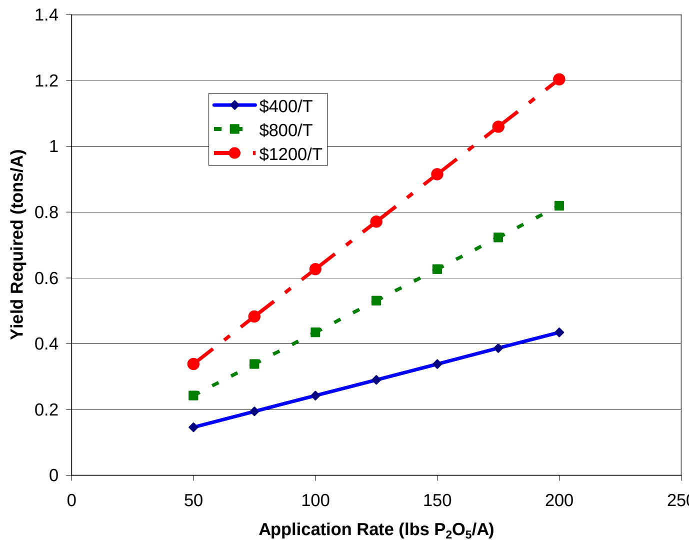

Figure 3. Seasonal yield increase needed to cover the cost of an application of 11-52-0 at three price levels. (Assuming an alfalfa hay price of $200 per ton and application cost of $10 /A. Does not include increase in harvest cost with higher yield.)

Since applications of phosphorus benefit the crop over periods of time, this yield benefit can be realized over a year or two period; but it must be exceeded for a fertilizer application to be defended on economic grounds.

In the past, the return on investment for a fertilizer application was typically 2:1 or 3:1 or even higher. However, with the significant increase in fertilizer costs over the last two years, the return on investment has dropped markedly. Therefore, growers should study these graphs carefully and assess the probability of a fertilizer application increasing yield to a level necessary to be economical.

Table 1. The effect of phosphorus rate and source on alfalfa yield, Lancaster CA.

		Yield (tons/A)						Increase
Treatment	**Lbs P_2O_5/A**	**Cut 1 4/30**	**Cut 2 6/10**	**Cut 3 7/14**	**Cut 4 8/21**	**Cut 5 10/2**	**Total**	**over unfertilized**
0-45-0	100	1.91	1.83	1.75	1.74	1.23	8.46	0.95
11-52-0	100	1.90	1.84	1.71	1.74	1.19	8.38	0.87
0-45-0	200	1.91	1.85	1.80	1.78	1.25	8.59	1.08
11-52-0	200	1.94	1.85	1.76	1.75	1.27	8.57	1.06
Untreated	0	1.56	1.65	1.57	1.60	1.13	7.51	—

Are yield increases of this magnitude with fertilizer application feasible? Numerous phosphorus application rate studies have been conducted over the years to determine yield responses to applied fertilizer. Consider the results of a trial conducted in Lancaster in the high desert of Southern California as an example (Table 1). There was a yield increase of approximately 0.9 tons/A per season for the 100 lb P_2O_5 application rate of either fertilizer source (11-52-0 or 0-45-0). Even at $1200 per ton 11-52-0 cost, fertilizing at this rate was justified as long as the hay price was greater than about $150 per ton. As shown in Figure 3, the 100 lb rate was justified at

$200 per ton hay value (a yield increase of approximately 0.9 tons occurred which is greater than a 0.6 yield increase needed) but increasing the rate to 200 pounds per acre was not justified because the yield needed to increase another 0.6 tons (far greater than the 0.2 ton increase actually observed).

Table 2. The effect of phosphorus rate on alfalfa yield, Scott Valley, CA. (Olsen P 2.4 ppm)

Rate Lbs P_2O_5/A	**Cut 1 6/12**	**Cut 2 7/21**	**Cut 3 8/28**	**Total**	**Increase over unfertilized**
Untreated	1.94	1.44	1.25	4.63	—
40	2.25	1.79	1.49	5.53	0.90
80	2.43	1.75	1.39	5.56	0.93
120	2.68	1.79	1.46	5.93	1.30
160	2.61	1.81	1.46	5.88	1.25

Table 3. The effect of phosphorus rate on alfalfa yield, Butte Valley, CA. (Olsen P 8.4 ppm)

Rate Lbs P_2O_5/A	**Cut 1 6/19**	**Cut 2 7/24**	**Cut 3 8/29**	**Total**	**Increase over unfertilized**
Untreated	2.39	1.83	1.33	5.56	—
40	2.68	1.93	1.35	5.96	0.40
80	2.89	2.03	1.48	6.41	0.85
120	2.98	2.10	1.50	6.63	1.07
160	2.88	2.03	1.46	6.37	0.81

EFFECTIVENESS OF DIFFERENT PHOSPHORUS APPLICATION METHODS

A significant portion of the phosphorus fertilizer applied to the soil becomes tied up and is rendered unavailable to the alfalfa plant. This is especially the case in calcareous and alkaline soils where the ability of the plants to take up phosphorus is impaired by the formation of poorly soluble calcium phosphate minerals. Applying phosphorus fertilizer in concentrated bands is a common practice in some crops to improve phosphorus availability. However, this is rarely done in alfalfa.

Field trials were conducted in Siskiyou and Lassen counties during the 2008 growing season to evaluate different application methods. Two trials were conducted in each county. The application methods evaluated were: 1) a broadcast application of granular 11-52-0 to the soil surface; 2) a banded application of 11-52-0 in 6 inch rows below the soil surface using a drill; and 3) a banded application of 10-34-0 to the soil surface using TeeJet StreamJet fertilizer nozzles that delivered three streams per nozzle. Yield was measured for all cuttings.

There was no difference in yield between application rates or application methods at the two Lassen County sites most likely due to the preexisting phosphorus content in these soils before the trials were initiated and the fertilizer treatments applied. One site had a pH of 7.3 and an Olsen P concentration of 10.1 ppm. The other site had a pH of 7.7 and an Olsen P concentration of 17.3 ppm. Historically, fields on this farm had been very low in phosphorus but the grower made phosphorus applications over the years to build up soil levels. The actual field where the trial was conducted had not received subsequent fertilizer applications for 3 years. This illustrates that even though this site had a previous history of phosphorus deficiency and a high pH (likely high phosphorus fixation rates); prior fertilizer applications had obviously improved phosphorus availability. This underscores the importance of soil or plant tissue testing before making the decision to fertilize even on fields with a previous history of deficiency.

At the Siskiyou County sites there was a significant increase in yield with the application of phosphorus fertilizer at both locations (Tables 2 and 3). However, there was no difference in yield between the three application methods indicating no improvement in phosphorus uptake with a banded application. However, banding phosphorus may be beneficial at locations with calcareous or alkaline soils.

ASSESSING THE NUTRITIONAL STATUS OF AN ALFALFA FIELD

To predict whether a fertilizer application will result in an economic return requires an accurate assessment of the current nutritional status of a field. Many growers currently fertilize based on past practice alone, virtually guaranteeing that many fields have either too much or too little fertilizer applied. Excess fertilizer applications increase production costs unnecessarily and in some cases can cause environmental degradation. On the other hand, too little fertilizer can result in dramatically lower yields and poor profitability.

Several diagnostic tools may be used to estimate the nutrient needs of a field. These include visual plant symptoms, soil analysis, plant tissue analysis, and fertilizer test strips to confirm a suspected nutrient deficiency.

Visual Plant Symptoms. As a rule, plant symptoms are unreliable because many deficiency symptoms are not definitive or readily observable. For example, phosphorus deficiency (the most common nutrient deficiency) is characterized by stunted plants with small leaves that are sometimes dark blue-green. However, these symptoms are also caused by several other common conditions including moisture stress. In addition, significant yield losses may occur before visual symptoms become apparent.

Soil Analysis. Soil analysis is a valuable diagnostic tool and its use should be encouraged. Guidelines to interpret the results of a soil test are presented in Table 4. However, soil tests only provide an estimate of what the plants may be able to uptake. They are more accurate for detecting some nutrient deficiencies than others (Table 5). However, plant tissue analysis is usually a better indicator because it more accurate reflects actual plant uptake. Soil tests are best prior to planting but thereafter plant tissue tests are usually superior to detect nutrient deficiencies.

Table 4. Interpretation of soil test results for alfalfa production.

	SOIL VALUE (PPM)			
NUTRIENT	**DEFICIENT**	**MARGINAL**	**ADEQUATE**	**HIGH**
Phosphorus	<5	5-10	10-20	>20
Potassium ammon. acetate	<40	40-80	80-125	>125
Potassium Sulfuric acid	<300	300-500	500-800	>800
Boron	<0.1	0.1-0.2	0.2-0.4	>0.4

Table 5. Relative reliability of soil and plant tissue testing for nutrient deficiency.

NUTRIENT	SOIL TESTING	TISSUE TESTING
Phosphorus	Good	Excellent
Potassium	Good	Excellent
Sulfur	Very poor	Excellent
Boron	Poor	Excellent
Molybdenum	Not recommended	Excellent

Plant Tissue Tests. Despite the reliability of plant tissue tests, most alfalfa growers at the present time do not conduct tissue testing to assess fertilization needs. The standard University of California (UC) recommended method for plant tissue analysis is to collect 40 to 60 stems from an alfalfa field at 10 percent bloom. The sample is divided into three parts (tops, mid stem, and mid-stem leaves). The lower third is discarded. The tops are analyzed for boron, molybdenum and copper, the mid stem leaf portion for sulfur, and the mid stem portion for phosphorus and potassium. Over the years this technique has proven to be valuable.

There are several drawbacks and practical considerations that have limited the adoption of this practice. This technique is time consuming. Growers are typically extremely busy during the season when fields are being cut and do not take the time to collect samples. Drying the samples and fractionating them into the respective plant parts is rather tedious and it is easy to forget which plant part is used for the different analyses. Samples must be collected prior to cutting obviously making it impossible to sample fields after the growing season is over. Many other alfalfa-producing states recommend using the top one-third of the plant for nutrient analysis. This is simpler than fractionating the plants, but the sample collection process is still time consuming and usually does not get done.

Cored Bale Samples For Nutrient Analysis. Many growers routinely take cored samples of haystacks for forage quality analysis (ADF, NDF, CP and DM). *Could these cored baled samples serve a dual purpose both forage quality analysis and to assess the nutritional needs of the crop?* If this technique is valid, it could be incorporated into routine testing practices and greatly simplify the tissue analysis process and reduce costs. Also, due to the fact that core sampling of hay stacks represents a wide range of plant material (greater than grab samples of the standing crop), it may be more successful at representing the overall nutrient status of a field.

A multiyear project was initiated to compare soil samples, cored-hay samples, whole top samples, and fractionated stem samples using the UC technique.

The results indicated that cored-baled samples provided results very similar to the fractionated stem samples. The mid-stem samples were analyzed for phosphate phosphorus (PO_4-P) and potassium and the mid-stem leaves were analyzed for sulfate sulfur (SO_4-S). Cored bale samples and whole-top plant samples were analyzed for PO_4-P, total phosphorus, total sulfur, SO_4-S, and potassium. Figure 4 shows the relationship between mid-stem PO_4-P concentration and the total phosphorus content of the cored bale samples. The two sampling methods were closely related. Likewise there was a strong relationship between the fractionated stem samples and cored bale samples for potassium and sulfur concentration. These results suggest that the cored bale sampling technique could be used successfully in lieu of fractionated stem samples.

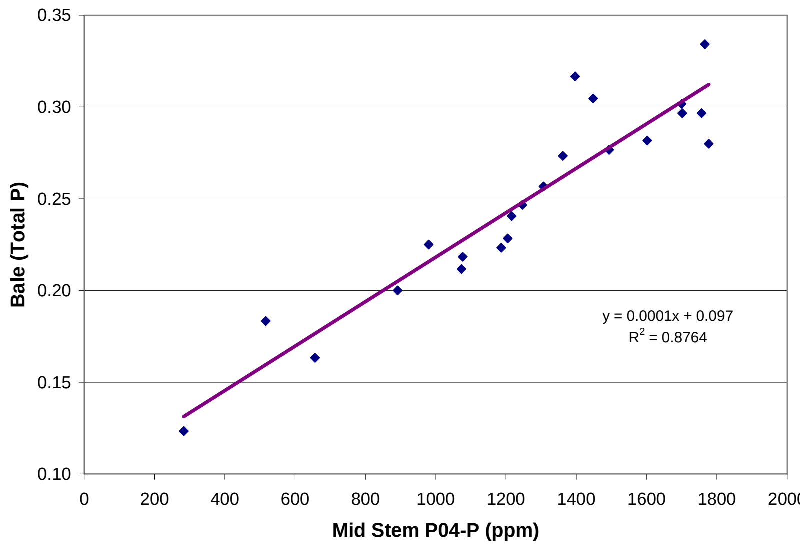

Figure 4. Relationship between mid-stem PO4-P concentration and the total phosphorus concentration of cored bale samples.

Current tissue level guidelines are based on alfalfa at one-tenth bloom growth stage. However, to produce highly digestible alfalfa for the dairy industry, growers harvest alfalfa in the bud stage and fields never reach one-tenth bloom. Additional research trials were conducted to evaluate the change in phosphorus concentration with advancing maturity for mid-stem and whole top samples. In agreement with the results of Schmierer *et al*., phosphorus concentration declined dramatically with advancing maturity. Therefore, plant maturity must be considered when interpreting plant tissue test results. For example, a sample collected at early bud may appear to have adequate phosphorus but if the same plants were sampled at one-tenth bloom they may be deficient. Further evaluation is needed before critical plant tissue levels can be recommended for bud-stage alfalfa.

EXTREME VARIATION IN NUTRITIONAL STATUS OF FIELDS

In the study mentioned above, numerous alfalfa fields throughout the Intermountain Region were sampled. A total of 117 samples were collected representing 39 fields (three sampling areas per field). Table 6 shows the results for some of the analyses. The range in values is striking. The average pH was 7.2 with values ranging from 5.6 to 8.1. This illustrates the diversity of soils encountered in the Intermountain Region. Soil phosphorus levels averaged 17.1 but ranged from a low of 2.0 (well below the deficiency level) to a high of 74.7 ppm (nearly 4 times the "High" level). Mid-stem phosphorus levels also averaged in the adequate range (1327 ppm) but ranged from 230 to 2220 ppm. Soil potassium levels ranged from very deficient (25 ppm) to extremely high (632 ppm) and averaged in the "High" range at 192 ppm. Tissue values also averaged in the "High" range but some locations were as low as 0.74 ppm K. Most of the Intermountain region has adequate or even high potassium levels but deficiencies occur in some isolated locations. The high tissue levels are not associated with potassium fertilization practices, but instead high inherent soil potassium levels. On average sulfur levels were high (2390 ppm) but ranged from 180 to 5350. This represents extremely deficient levels to over 5 times the high level.

Table 6. The average and range of soil test values (pH, Olsen P, and K) and plant tissue levels (PO4-P, K and SO4-S) found for 117 samples collected from 39 alfalfa fields in the Intermountain Region of northern California.

	Soil			**Mid-Stems**		**Mid-Stem Leaves**
	pH	**Olsen P** Ppm	**K** ppm	**PO_4-P** Ppm	**K** %	**SO4-S** ppm
Average	7.2	17.1	192	1327	2.03	2390
Low	5.6	2.0	25	230	0.74	180
High	8.1	74.7	632	2220	4.18	5350
Deficient		<5	<40	300–500	0.4–0.65	0–400
Marginal		5–10	40-80	500–800	0.65–0.80	400–800
Adequate		10–20	80-125	800–1500	0.80–1.50	800–1000
High		>20	>125	Over 1500	>1.5	Over 1000

The significance of this table is that it illustrates how much nutrient levels can vary between fields depending on the inherent fertility of the soil and past fertilization practices. To predict whether you will have an economic response to fertilizer, it is critical that you use soil tests or plant tissue tests to evaluate the current status of the field. The yield response from a fertilizer application is far greater if the field is deficient than if soil tests or plant tissue tests indicate that the fertility status of the field is in the medium or adequate range.

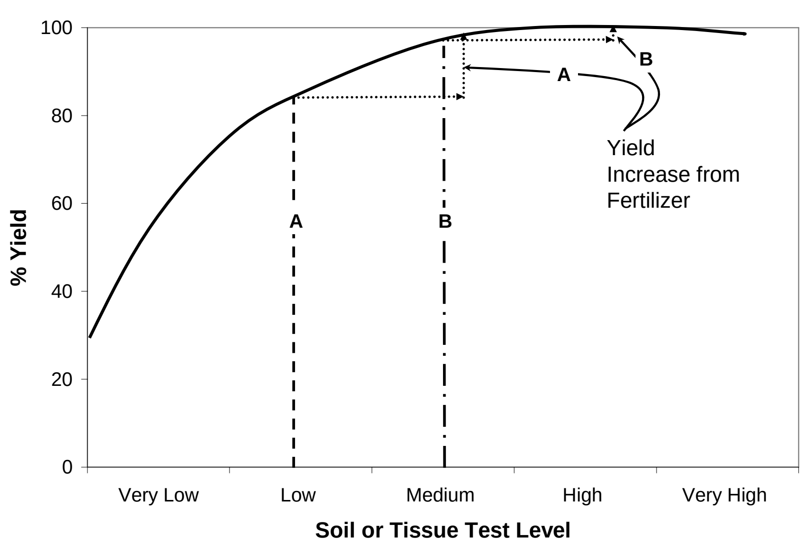

Figure 4. Nutrient response curve illustrating the likely yield response from fertilizer applied to fields with different fertility levels as indicated by soil analysis or plant tissue test. Note the yield increase is far greater when fertilizer is applied to the "Low" fertility field (A) compared with the "Medium" fertility field (B). Therefore, it is much easier to justify the cost of fertilizer for field A than for field B.

CONCLUSION

The decision whether to fertilize alfalfa and how much to apply is increasingly difficult with current fertilizer prices. An economic response from fertilizer application depends on the fertilizer price, alfalfa value and the fertility status of the field. In the past when phosphorus and other nutrients were one third of their current cost, maintenance applications were often economical but that may not be the case today. It is more important now than ever to use soil tests or plant tissue tests (either fractionated stem samples or cored bale samples) to have a more accurate assessment of the fertility status of a field. With current fertilizer prices, the likelihood of an economic fertilizer response is low for soils in the adequate range and extremely rare for soils in the high range. However, if a field is deficient yield increases of the magnitude needed to justify the high cost of fertilizer are feasible. When fertilizer is needed, be sure to make the application at least 60 to 90 days before first cutting. In all the studies we conducted the greatest yield increase occurred at first cutting (higher yield potential and lower phosphorus uptake due to colder soils and slower root growth).

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