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Keith A. Kelling
University of Wisconsin–Madison

John B. Peters
University of Wisconsin–Madison

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ALFALFA FERTILITY MANAGEMENT
FOR PRODUCTION AND FEED QUALITY

Keith A. Kelling
Professor and Extension Soil Scientist
Department of Soil Science
Univ. of Wisconsin-Madison

John B. Peters
Director
UW Soil and Forage Analysis Laboratory
Marshfield, Wisconsin

Introduction

For many years it has been recognized that the two major limiting factors to alfalfa (Medicago sativa) growth in the upper Midwest are soil pH and exchangeable soil potassium (Brown, 1928; Hull, 1934; Lanyon and Griffith, 1988). Recent research affirms the benefits of raising pH to near neutral by adding lime to fields where alfalfa is to be grown in Wisconsin (Peters and Kelling, 1989; Peters and Kelling, 1997).

Potassium is removed from the soil by alfalfa in amounts greater than any other nutrient and there is substantial documentation of the benefits of adding supplemental potash to soils where alfalfa is to be raised (Attoe and Truog, 1950; Peterson et al., 1975; Smith and Powell, 1979; Erickson et al., 1981; Kelling, 1995). Research from Wisconsin has shown that potassium is required to enhance resistance to disease and lodging, and winter hardiness of alfalfa (Kelling, 1991). Additionally, potassium is involved in carbohydrate production and transport, enzymatic activity, and stomatal function in alfalfa (Munson, 1985). Potassium also balances the negative charges of organic and inorganic anions within the plant.

Dairy cattle nutritionists have been placing increased importance on balancing the ionic composition (cation:anion ratio) of rations in recent years. Concern has been raised as to the amount of potassium in forage tissue, and the impact this has on the ionic balance of dairy feeds. High cation:anion diets fed to dry cows have been shown to increase the potential for cattle to develop milk fever at freshening (Moore et al., 2000). Furthermore, in lactating diets, excessively high potassium levels have been shown to interfere with magnesium absorption. In an attempt to “rebalance” the ions in harvested forages, various components of the farm service industry have promoted the application of small amounts of calcium to alfalfa fields. For most producers in Wisconsin, the primary source of soil calcium is applied aglime or limestone containing parent material.

This paper presents the results of several recent Wisconsin experiments that have examined

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alfalfa responses to lime and applied K and the impact these treatments have had on forage quality.

Responses to Aglime

Figure 1 shows results of a recent Wisconsin study that confirm in areas of the state where soil pH is inherently acidic, the pH should be adjusted into the 6.5 to 7.0 range if alfalfa is to be grown. In this study, the average annual dry matter yields when the soil pH was at least 6.5 or higher were approximately 187, 250, and 410% of the yields found at the lowest treatment levels (pH 4.5 to 4.8) for the Hancock, Marshfield, and Spooner locations, respectively. A significant interaction between soil pH and K application rates was observed for dry matter yield at all three locations. This interaction showed that there was little yield response to K at the lower pH levels, but if the soil was limed adequately, substantial response to topdressed K was observed.

![Figure 1](image-url)

Figure 1. Alfalfa yield response to changes in soil pH at three Wisconsin locations (average 1998 to 2001).

One of the key factors in the yield response is the influence that soil pH has on alfalfa stand survival. The final crown count taken at each location showed an increase of from 3.3 to 4.4 plants per square foot (pl/ft²) at Hancock, 0 to 7.3 pl/ft² at Marshfield, and 1.2 to 7.8 pl/ft² at Spooner, when comparing the lowest pH level with the 6.5 to 6.8 pH treatment level. The greatest influence of pH on stand was found on the heaviest textured soil of the three (Withee silt loam at Marshfield) and the least impact on the lightest textured soil (Plainfield loamy sand at Hancock). Apparently, the increased likelihood of periodic wet soil conditions on these soils that are not as well drained increased the impact of the adverse effects of attempting to grow alfalfa at less than optimum pH levels. The significant interaction of pH x K on stand at this site also shows that benefit from K is only possible if the soil pH is greater than 5.5.

The lime plots at Hancock have also compared the responsiveness from using dolomitic versus calcitic lime at two of the pH levels (6.0 and 7.0). Over the several years of this study, no yield, forage quality, or stand differences were observed between the two sources with yields...
from the dolomitic treatments averaging 3.62 versus 3.68 tons/acre for the calcite treatments. These results are similar to those obtained from several previous studies (Schulte and Kelling, 1987; Kelling et al., 1996), and although some states have demonstrated a slightly more rapid neutralizing reaction with calcitic lime, we recommend that the most cost effective material be used, based on chemical purity and fineness of grind.

**Effect of Potassium**

The importance of adequate potassium for alfalfa is well illustrated by an experiment conducted at Arlington, Wis. from 1994 to 1997. In this experiment, six annual topdressed K$_2$O rates from 0 to 350 lb K$_2$O/acre/year were superimposed on five initial soil test K levels ranging from 69 to 166 ppm K. Table 1 shows the interactive effects of soil test and top-dressed K on yield, forage quality, and tissue cation levels for the low, medium, and highest initial soil test K levels. Soil test K clearly influenced yields in each of the years, with yields plateauing at about 120 ppm in most years. These data are consistent with a variety of Wisconsin studies, including Peterson et al. (1975), Kelling (1984), and Kelling et al. (1995). Interestingly, the addition of topdressed K$_2$O did not statistically affect yields in the first year, although there appeared to be a small increase (approximately 0.12 ton/acre) to the first K$_2$O rate. However, in subsequent years, the main effect of topdressed K$_2$O was significant up to about 210 to 280 lb K$_2$O/acre/year.

It is apparent from these data that both soil test and topdressed K are contributing to the K nutrition of the plant. Obviously, more topdressed K$_2$O is needed to optimize yields when soil tests are low and less is needed at the higher soil test K levels. At initial soil test K levels of greater than 150 ppm, little response to topdressed K$_2$O was seen. These data also show that if topdressed K$_2$O is not going to be applied, initial soil test K needs to exceed 150 ppm for top yields to be obtained. However, if topdressed K$_2$O is applied, there is little advantage to holding soil tests at this elevated level since top yields could be obtained with adequate amounts of topdress fertilizer alone.
Table 1. Effect of selected soil test K and annual topdressed K$_2$O rates on average alfalfa yield and quality at Arlington, Wisconsin (1994 to 1997). †

<table>
<thead>
<tr>
<th>Initial soil test K level</th>
<th>Topdress K$_2$O rate</th>
<th>Dry matter yield</th>
<th>NIRS forage quality†</th>
<th>Tissue concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>ppm</td>
<td>lb/acre/year</td>
<td>ton/acre</td>
<td>Crude protein</td>
<td>ADF</td>
</tr>
<tr>
<td>69</td>
<td>0</td>
<td>2.95</td>
<td>24.1</td>
<td>28.9</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>3.26</td>
<td>24.6</td>
<td>29.4</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>3.34</td>
<td>24.1</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td>210</td>
<td>3.36</td>
<td>24.3</td>
<td>29.5</td>
</tr>
<tr>
<td></td>
<td>280</td>
<td>3.72</td>
<td>23.9</td>
<td>30.8</td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>2.86</td>
<td>23.4</td>
<td>30.9</td>
</tr>
<tr>
<td>85</td>
<td>0</td>
<td>3.27</td>
<td>23.3</td>
<td>29.9</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>3.34</td>
<td>24.0</td>
<td>30.6</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>3.37</td>
<td>23.8</td>
<td>30.0</td>
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<tr>
<td></td>
<td>210</td>
<td>3.60</td>
<td>23.9</td>
<td>31.2</td>
</tr>
<tr>
<td></td>
<td>280</td>
<td>3.63</td>
<td>23.4</td>
<td>30.8</td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>3.64</td>
<td>23.3</td>
<td>31.7</td>
</tr>
<tr>
<td>166</td>
<td>0</td>
<td>3.55</td>
<td>23.4</td>
<td>30.2</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>3.51</td>
<td>23.4</td>
<td>30.1</td>
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<tr>
<td></td>
<td>140</td>
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<td></td>
<td>210</td>
<td>3.61</td>
<td>23.3</td>
<td>30.7</td>
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<td></td>
<td>280</td>
<td>3.52</td>
<td>23.0</td>
<td>31.2</td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>3.58</td>
<td>23.2</td>
<td>31.2</td>
</tr>
</tbody>
</table>

† Adapted from Kelling and Speth (1998).

‡ Third cutting average across years.

Results of the NIRS evaluation of the third cutting for each year show a decrease in crude protein content with increasing soil test K levels and topdressed K$_2$O applied. Since all treatments were applied as K$_2$SO$_4$, these data do not support the hypothesis that excess sulfur should be provided to increase protein content. There was also a tendency for increasing acid detergent fiber (ADF) and neutral detergent fiber (NDF) levels with increasing soil test K and topdressed K$_2$O rate. Since stand was not affected by treatment, it is likely that the increased level of K accelerated crop maturity, which resulted in the slight protein depression and increase in fiber.

Average tissue cation levels for the third cutting forage show that increasing K from either soil test or topdressed K$_2$O resulted in more K in the harvested tissue up to average levels of about 4.10%. Increasing K from either source did not increase tissue K above this plateau. It is also clear that as tissue K increased, tissue Ca, and especially tissue Mg, decreased. The relative
increase in tissue K, or decrease in tissue Ca or Mg, remained about the same when similar amounts of topdressed K$_2$O were applied irrespective of the initial level soil test K present.

At soil tests above 120 ppm soil test K, adding more than 160 lb K$_2$O/acre/year resulted in forage K levels above 3.50% with no increase in yield. From a ration balancing standpoint, this forage would not be suitable for dry cows or springing heifers due to its high K content. Conversely, at soil tests < 110 ppm, either 200 or 280 lb K$_2$O/acre/year was needed to maximize yield, and these levels did not result in more than 3.5% K in the forage.

**Avoiding Excessive Tissue Potassium**

The K content of harvested forage has become an increasingly important issue in recent years. As most dairy producers already know, a high level of K in forage has been identified as the causative factor for milk fever in dry and transition cow diets. Hypocalcemia results from a deficiency in plasma calcium at the onset of lactation in dairy cows and is the main cause of several severe metabolic disorders. Three weeks prior to calving, it is recommended to have a moderately anionic diet to avoid milk fever and hypocalcemia. It is during this period that low K forages are desirable. Immediately after calving, a cationic diet is essential. Milking dairy cattle can tolerate forage that has a high K concentration during lactation because they can void the excess K in the milk. Increasingly, buyers and sellers of hay base purchase decisions on forage tissue K content. Dairy producers are seeking strategies to lower the K content of harvested forage.

All forages, except corn silage, grown on the same ground contain similar K levels at the same stage of maturity. As the data in Table 2 indicate, seeding ryegrass with alfalfa did not affect the K concentration of the harvested forage. National databases of forage composition, such as those in the National Research council requirements for dairy and beef animals, list lower K concentrations for some grasses than legumes. This simply means that grasses, on the average, are grown in lower K soils. In fact, grasses tend to be more efficient than legumes in their ability to extract K from the soil. For this reason, grasses will often be at or above tissue K levels reported for alfalfa when grown on soil at the same soil test K level. Adding a grass to your forage establishment mix will usually not result in lower tissue K levels of the harvested forage.

There are some strategies that can be used to generate lower K forages. These strategies are only useful, however, when the producer has a convenient system for segregating and storing the low-K material for dry cow use.
Table 2. Comparison of forage potassium levels of legume and legume-grass mixtures, Ashland, Wisconsin, 1994.†

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cut 1</th>
<th>Cut 2</th>
<th>Cut 3</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% K</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Alfalfa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solo</td>
<td>3.82</td>
<td>2.97</td>
<td>2.36</td>
<td>3.05</td>
</tr>
<tr>
<td>With ryegrass</td>
<td>3.45</td>
<td>3.80</td>
<td>2.24</td>
<td>3.16</td>
</tr>
<tr>
<td><strong>Red clover</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solo</td>
<td>3.50</td>
<td>3.77</td>
<td>2.38</td>
<td>3.22</td>
</tr>
<tr>
<td>With ryegrass</td>
<td>4.14</td>
<td>3.26</td>
<td>2.56</td>
<td>3.32</td>
</tr>
<tr>
<td><strong>Birdsfoot trefoil</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solo</td>
<td>3.14</td>
<td>3.22</td>
<td>2.42</td>
<td>2.93</td>
</tr>
<tr>
<td>With ryegrass</td>
<td>4.33</td>
<td>2.92</td>
<td>2.86</td>
<td>3.37</td>
</tr>
</tbody>
</table>

† From Mlynarek et al. (1994, personal communication).

1. Soil test and add K only as recommended — It is well documented that alfalfa will take up K beyond its needs if high levels of soil or applied K are available. This is referred to as “luxury consumption” and is demonstrated in Table 1. Typically, alfalfa yields plateau at about 120 to 140 ppm soil test K. At this level, approximately 200 lb of K₂O needs to be applied annually as topdress to optimize yield and to maintain soil test levels. Little to no yield response to topdress K is expected when soil test K exceeds 150 ppm.

2. Cut alfalfa close to the soil surface — Potassium tends to be concentrated more in the stems than the leaves and is even more concentrated in the upper stems (Rominger et al., 1975). Therefore, cutting low to include as much stem as possible will cause the resulting forage to be lower in K, as shown in Figure 2 (Wiersma and Peters, 2000).

3. Harvest mature forage for transition cows — As legumes and grasses mature, their K content declines. Alfalfa was found to decline from 2.75% to nearly 1.75% K from late vegetative to one-fourth bloom (Baker and Reid, 1977). Similar work at the UW Marshfield Research Station showed that from late vegetative to full bloom, K levels in alfalfa dropped from 3.21% to 2.08%. At the same site, bromegrass from second node to late heading dropped from 3.01% to 2.41% K. Grasses at flowering may have half the K concentration of immature forage earlier in the season.

4. Harvest rained-on forage for transition cows — Potassium is not a part of any plant structural compound. It is in the cell solubles and therefore very readily leached from the plant when rain falls between mowing and harvest. In Wisconsin, during 2001, 0.6 inch of rain reduced tissue K from 2.55% to 1.90% K.
Figure 2. Effect of alfalfa cutting height on herbage potassium content, Marshfield, Wisconsin (Wiersma and Peters, 2000).

Although NIRS is a useful forage quality assessment tool, the University of Wisconsin recommends wet chemistry mineral analysis for balancing feed rations. Do not buy, sell, or feed forage based solely on an NIRS analysis for K concentration. Comparison studies have shown that NIRS analysis does not do a good job of segregating unusual tissue cation situations. This technique tends to under-estimate levels when very high quantities are present and over-estimate very low concentrations. If tissue cation levels are a major concern, spend the extra money to have the determination done with wet chemistry techniques. Use results from NIRS testing only as guides to identify very high or very low testing K forages.

Summary

The data from these experiments show the benefits of a strong forage fertilization program, especially for liming and potassium. This work demonstrates that a pH of 6.7 or above is needed for top yields and quality and either soil test K, topdressed K₂O, or a combination of both can be used to optimize alfalfa yields. At soil test K levels of 90 to 120 ppm (approximate Wisconsin's current optimum range), about 200 lb K₂O/acre/year should be top-dressed. Where soil test K levels are lower, somewhat more should be applied, and where soil test exceeded 150 ppm, little benefit was seen to topdressing. About 200 lb K₂O/acre/year appeared to maintain soil test K levels even though removals may have been significantly higher. The use of excessive amounts of potash should be avoided, especially where feed for dry cows and freshening heifers are being produced. Techniques for minimizing forage K levels include following soil test K recommendations, cutting forage lower, allowing some forage to manure longer, and using rained-on hay for dry cows.

References


Munson, R.D. 1985. Potassium in agriculture. ASA/CSSA/SSSA, Madison, WI.


