

ALFALFA RESPONSE TO K AT VARIOUS SOIL pH LEVELS

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Past research in Wisconsin and other mid-western states has shown that alfalfa will perform best when grown on well drained, near neutral soils that have adequate nutrition. In Wisconsin, potassium is of special concern because this nutrient is often needed for this crop. Potassium functions in several physiological processes in forage legumes. These include enzyme activity, carbohydrate production and transport, and stomatal activity (Munson, 1985). Wolf et al. (1976) found that K increased the carbon dioxide exchange rate of leaves. Peoples and Koch (1979) found that K deficiency slowed the rate of growth of both the shoots and roots and increased the rate of maturation to first flower. Potassium also balances the negative charges of organic and inorganic anions within the plant and appears to be involved in starch formation, translocation of sugars, nitrogen assimilation and several other metabolic processes. Potassium uptake is also linked to increased resistance to disease and lodging, increased carbohydrate production, and improved winter hardiness of alfalfa (Schulte and Walsh, 1993). The response of alfalfa to additional K may reflect the influence of this element on one or several of these factors.

There are three forms of soil potassium in soils. These include the readily available or exchangeable, slowly available and unavailable. The unavailable K is contained with the crystalline structure of rocks and minerals. The slowly available forms are associated with clay minerals and is related to the soils ability to supply K over a long period of time (buffer capacity). The readily available form is what is measured by soil tests. Clay and organic matter hold K^+ ions in an exchangeable form and is, therefore, somewhat pH dependent. There is a decrease in exchangeable K as soil pH decreases below the optimum level for alfalfa as well as when the pH is above 7.0. Maximum availability occurs when the soil pH is the range of 6.0-7.0.

A significant amount of published and unpublished data exists that demonstrate the responsiveness of alfalfa to K on Wisconsin's soils (Attoe and Truog, 1950; Smith, 1975; Rominger et al., 1976; Smith and Powell, 1979; Erickson et al., 1981; Peterson et al., 1983; Kelling, 1984; Kelling et al., 1995). These experiments helped identify the soil test K level above which yield response is not observed. This level was established as the bottom of the "high" soil test interpretive range (Kelling et al., 1991). These data also show that responses to annual topdressed K were generally optimized between 200 and 300 lb K_2O /acre, especially if soil tests were in the optimum range or lower. Recent

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experiments showed that alfalfa responded to either topdressed or soil test K or a combination of both (Kelling and Speth, 1997). Similarly, a substantial amount of work has documented the benefits of lime to alfalfa (Kelling et al., 1982; Peters and Kelling, 1989, 1997).

Methods and Materials

This study was conducted at the long-term pH plots located at three UW Agricultural Research Stations. These plots at Spooner, Marshfield and Hancock have pH levels ranging from about 4.8 to 7.0 in five, six or six levels, respectively. In addition, Hancock also has two pH levels (6.0 and 7.0) limed with either calcitic or dolomitic lime. The potassium variable in this study consists of an annual application of 0, 100, 200 and 400 lbs K₂O per acre, applied following first cutting in each year of the study.

The Marshfield plots were direct seeded to the Innovator+Z alfalfa in the spring of 1997. Potassium treatments were not applied in the seeding year and yield measurements were not made. The first cutting in 1998 was discarded due to excessive weed pressure and the initial topdress K treatments were applied following this cutting. Two subsequent harvests were made in 1998 and three in 1999 with the second application of topdressed K made following the first cutting in 1999.

The studies at Spooner and Hancock were begun a year later, with direct seedings of Dekalb DK 133 and Legendairy 2 alfalfa, respectively, made in the spring of 1998. An application of 150 lbs NH₄SO₄ was made at the time of seeding because of the relatively low organic matter content of the soils at these locations. In both cases, the first cutting in this seeding year was discarded due to excessive weed pressure. The first application of topdressed K was made following this first cutting and one measured harvest taken at both locations in August 1998. Three harvests were made at each location in 1999, with the second annual application of K made after first cutting.

Harvests were made using a small plot harvester that cuts a 34-inch swath. A forage tissue sample was taken from each plot for dry matter determination and subsequent fiber and mineral analyses. These samples will be analyzed by ICP spectroscopy and NIR analysis and used to study the interaction of tissue mineral levels with soil pH and topdressed K levels. Soil samples were taken from all plots following the final cutting in both of the study years. Stand counts and weed evaluations were done at the Hancock location following third cutting in 1999. The UW Soil and Forage Analysis Laboratory at Marshfield and the UW Soil and Plant Analysis Laboratory at Madison performed all analyses.

Results and Discussion

At the Marshfield location, soil pH had a significant effect on alfalfa yield for both cuttings and total yield in 1998 (Table 1). Total yield was increased from 1.25 t/a at pH 4.26 to 1.98 t/a at pH 6.84. The K rate and interaction of K rate and soil pH had no influence on alfalfa yields. Similarly, in 1999, soil pH had a significant effect on all cuttings and total yield. In this year, total yield was increased from 1.15 t/a at the lowest pH (4.36) to 4.03 t/a at pH 6.95. There was a significant effect of K rate on third cut yield ($P > F = 0.06$). The interaction of pH and K rate was significant for second cutting. The response to applied K was greater at higher pH levels where the acid soil conditions are no longer limiting yields. Total alfalfa yield was increased from 2.91 t/a at the 0 K rate to 3.15 t/a at the 100 and 200 lbs/K₂O/a/year treatment level.

Soil pH had a significant effect on the 1998 alfalfa yield at Spooner. (Table 2). The yields were increased from less than 0.5 t/a at the lower pH levels (pH < 5.5) to 0.72 t/a at the high pH level (pH = 6.84). The interaction of K rate and pH also had a significant effect on yield, although K rate alone did not. The addition of K at the low soil pH levels resulted in a reduced dry matter yield that was likely the result of a salt effect. At higher pH levels the addition of K resulted in a positive yield response. There was a significant effect of soil pH on all three cuttings and the total yield from 1999. Total dry matter yield was increased from 0.63 t/a at the lowest pH (4.76) to 3.94 t/a at the highest pH level (7.11). The K rate and interaction of K rate and pH did not have a significant effect on yield in 1999 which was surprising as the soil test K levels were in the modest range of about 86 ppm.

Alfalfa dry matter yields in 1998 were not significantly affected by soil pH or K rate at the Hancock location (Table 3). In 1999, however, soil pH had a significant effect on all three cuttings in addition to total yield, crown count and weed content. Total yield was increased from 1.00 t/a at the lowest pH level (5.30) to 3.30 t/a at the highest pH level (6.80). The average crown count was more than doubled from 3.3 plants/ft² at pH 5.30 to over 6 plants/ft² when the soil pH was above 6.0. There was a decline in the stand at the low soil pH levels when K was applied and an increase in stand at the high pH levels when K was applied. The stand decline at the low pH levels is likely a result of the negative impact of the high salt level associated with this treatment. A visual evaluation of the stand at the time of third cutting showed that alfalfa density increased as pH increased from 5.30 to about pH 6.0 or above. The K rate had a significant effect on third cut yield and total yield. In both cases, the highest yields were seen where 100 or 200 lbs K₂O/a/year had been applied. The application of 400 lbs K₂O/a/year seemed to be slightly detrimental to yield.

Summary

In all cases except for the one cutting taken in the seeding year at Hancock, soil pH had a significant effect on alfalfa dry matter production. In 1999, the magnitude of this dry matter yield response for the total of the three cuttings ranged from 525% at Spooner to 250% at Marshfield and 230% at Hancock. It appears that the annual application of K increased dry matter yield at Marshfield in 1999, but had little effect at Spooner. At Hancock, applying some K was advantageous, but the application of 400 lbs K₂O annually appears to be somewhat excessive and yields were slightly reduced. At all three locations, the soil test K was in the modest range (70-97 ppm) without the addition of K. There was more of a response to K in the later cuttings in 1999 and we would expect there will be more interaction in subsequent years of this study as soil test K becomes more depleted when no additional K is applied. When the soil acidity problem is corrected and no longer limiting yields, we would expect alfalfa to respond more positively to K treatments. The study will continue in 2000.

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