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Alfalfa Yield and Soil Test Responses to Phosphorus and Potassium

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Phosphorus (P) and potassium (K) fertilizer rate trials indicated pre-1997 Utah State University P and K fertilizer recommendations should be increased to reflect current yield levels and soil conditions. A higher critical soil test P value was also indicated, but more data need to be collected to identify the critical soil test K value. Soil sample depth and time of year have significant effects on soil test values and resulting fertilizer recommendations. These protocols must be standardized for routine sampling by farmers and agronomists.

Alfalfa is grown on about 7.4 million acres in the western U.S. and on more acres than any other crop in Utah. In the past, Utah P and K recommendations were based on alfalfa yields of 4 to 4.5 tons/A. Growers in many areas are now reporting yields as high as 8 tons/A. In addition, the frequency of low P and K testing soils has increased in alfalfa fields, and more visual symptoms of P and K deficiency have been observed by field agronomists and county agents.

The primary objective of this project was to evaluate P and K fertilizer recommendations for alfalfa and, if necessary, recalibrate the sodium bicarbonate ($NaHCO_3$) soil test for current crop yield potentials and soil conditions. A secondary objective was to evaluate the effects of sampling depth and time of year on soil test P and K levels and fertilizer recommendations.

Experiments were initiated at six sites between 1996 and 1998 (**Table 1**). Five of the sites were located in growers' fields, and one site (Cache) was located on a Utah State University Experimental Farm in Logan. Each experiment consisted of separate P and, if soil tests indicated a deficiency, K rate trials. Fertilizer rates of 0, 50, 100, 200, and 300 lb P_2O_5 or K_2O per acre were broadcast in late fall or early spring on established alfalfa stands. Each treatment was replicated three times in a randomized complete block experimental design. Yield and $NaHCO_3$-extractable P and K were measured for two a minimum of production seasons at each location.

Fertilizer rate effects. Yield ranged from 4.1 to 7.9 tons/A across sites. Annual responses to P fertilizer ranged from 0.6 to 1.9 tons/A. Pre-1997 Utah State University P recommendations were described as being for 2 to 3 years of alfalfa production. At sites where 2 full years of data are presently available, cumulative alfalfa yield responses occurred at P rates two to four times higher than pre-1997 recommendations (**Table 2**). At the lowest P testing site, the response to P rate was linear up to 300 lb P_2O_5/A. Responses to K ranged from 0.4 to 0.7 tons/A. Responses were higher than pre-1997 recommendations at two of three sites (**Table 2**). At the lowest K testing site, the response to K was linear up to 300 lb K_2O/A. Based on these results, Utah State University P and K fertilizer recommendations for alfalfa were increased in 1997 by 20 to 50 lb/A P_2O_5 or K_2O in each soil test category. Recommendations will be further refined as additional data are collected.

Fertilizer-soil test-yield correlations. The critical soil test P concentration (0 to 12 inch sample depth) was between 15 and 20 parts per million (ppm), as shown in **Figure 1**. This is higher than the previous critical value of 10 ppm used as a cutoff for fertilizer

recommendations. Considerable variability in soil test response to P application was evident among sites. For example, at the Sevier location the application of up to 300 lb P_2O_5/A increased soil test P linearly from 9 to 42 ppm (slope = 0.11 ppm P per lb P_2O_5/A), while at the Weber site the same rates of fertilizer increased soil test P linearly from 4.7 to 16.7 ppm (0.04 ppm P per lb P_2O_5/A).

TABLE 1. Selected soil properties of the P and K fertilizer rate study sites.

Location	Soil texture	pH	%CCE[2]	$NaHCO_3$-extractable[1] P, ppm	$NaHCO_3$-extractable[1] K, ppm
Cache	silt loam	7.8	37	9.0	95
Grand	loam	7.9	22	10.0	119
Sevier	clay loam	8.1	54	8.9	70
Weber	silty clay loam	7.1	0	4.2	105
Carbon[3]	loam	7.9	23	4.1	221
Uintah[3]	loam	7.7	4	7.7	179

[1]0 to 12 inch sampling depth
[2]Calcium Carbonate Equivalent
[3]P-only site

TABLE 2. Pre-1997 Utah State University fertilizer recommendations and alfalfa responses to P and K fertilizer rates at three of the study sites. Results from the other three sites are being collected in 1998-1999.

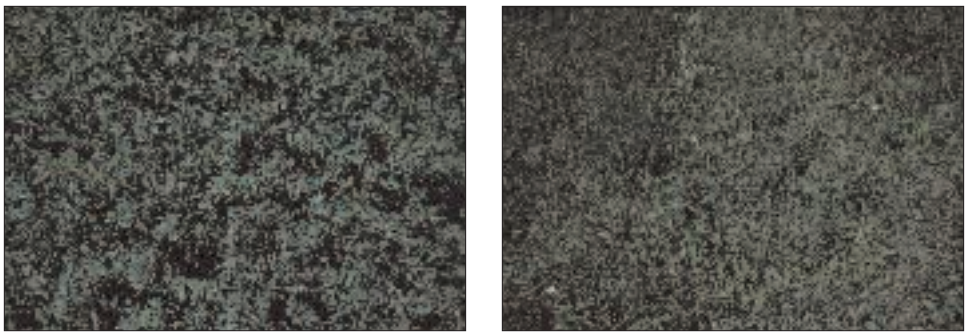
County location	Pre-1997 P recommendation (lb P_2O_5/A)	2-year cumulative yield response (lb P_2O_5/A)	Pre-1997 K recommendation (lb K_2O/A)	1-year K response (lb K_2O/A)
Cache	40 to 60	200	80 to 120	100
Sevier	40 to 60	100	140 to 180	≥300[1]
Weber	70 to 90	≥300[1]	0	100

[1]Response was linear over the range of fertilizer rates evaluated.

At the Weber site, soil test P in the unfertilized treatment declined to 3.2 ppm after 2 years, and severe P deficiency symptoms were observed, as shown at right below.

A critical soil test K value could not be defined with the limited database currently available (**Figure 2**). At these sites it has been difficult to generate sufficiently high soil test K values with the range of K fertilizer rates applied. For example, at sites testing near or below 100 ppm K, the application of 300 lb K_2O/A produced soil test K values of only 85 to 122 ppm. Subsequent applications of 600 lb K_2O/A in 1997 increased soil test K from 93 to 111 ppm at the Weber site and from 79 to152 ppm at the Sevier site. These applications produced higher yields than the 300 lb K_2O/A treatment at both locations, but were not a part of the original treatment structure.

Soil test K in control (unfertilized) treatments at two locations has declined to 50 to 75 ppm after 2 years of cropping. At one site (Cache), low soil test K has lead to severe K deficiency symptoms and yield reductions of up to 40 percent in the first two cuttings of the 1998 crop year. Potassium deficiency



A P fertilized plot (left) and severe P deficiency in a control plot (right) at the Weber site (control plot soil test P = 3.2 ppm).

symptoms are shown in photo at right below.

The importance of P and K fertilization on low testing sites is clear. However, soil test responses to fertilizer application have been variable among sites. In addition, relationships among fertilizer rate, soil test value, and alfalfa yield have thus far been more difficult to define for K than for P. In addition to revising P and K fertilizer recommendations for alfalfa, we increased the critical soil test P concentration to 15 ppm and continue to work on identifying the critical soil test K concentration. Based on the variability in soil test response to fertilizer application among sites, we are now recommending that alfalfa growers soil test more frequently until deficiencies are corrected, especially on very low P and K testing sites.

Soil samples collected at 0 to 4 or 0 to 6 inch depths were 1.4 to 2.2 times higher in soil test P and 1.1 to 1.8 times higher in soil test K than 0 to 12 inch depth samples. As a result of the higher soil test values, sampling to depths less than 12 inches would result in inaccurate (lower) fertilizer recommendations. Since soil test correlation databases are based on a uniform 12 inch sample depth, routine soil sampling must be to the same depth in order to make accurate fertilizer recommendations.

Time of year also affected soil test P and K at two of the three sites evaluated. During the year, soil test values peaked in early spring, were lowest during midseason, and increased after alfalfa entered dormancy in fall. Depending on the site and time of year samples are collected, soil test values and the resulting fertilizer recommendations could vary considerably. BC

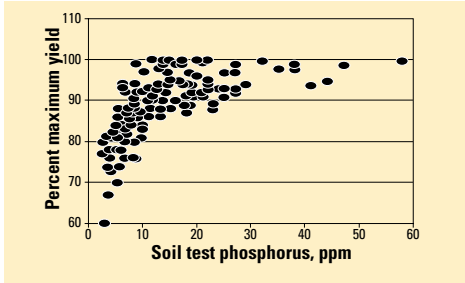


Figure 1. Relationship between soil test P and percent maximum yield. Data points are for 7 site-years.

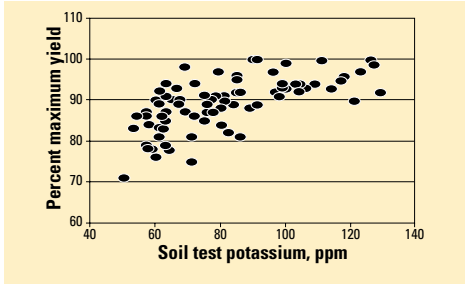


Figure 2. Relationship between soil test K and percent maximum yield. Data points are for 4 site-years.

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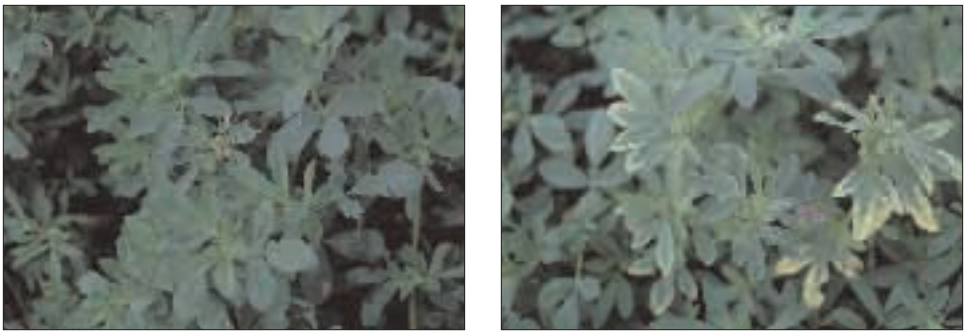

A K fertilized plot (left) and severe K deficiency in a control plot (right) at the Cache site (control plot soil test K = 53 ppm).