ALFALFA RESPONSE TO K RATE, SOURCE AND TIME OF APPLICATION[1/]

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The potassium (K) requirement of alfalfa is greater than that for any other nutrient. Potassium influences several systems within alfalfa plants, including enzyme activity, carbohydrate production and transport, stomatal activity, photosynthesis through chlorophyll content and CO_2 exchange rate, and nitrogen fixation (Munson, 1985). Potassium also markedly influences alfalfa agronomically through yield increases and improvements in forage quality, disease resistance, and overwinter survival.

A significant amount of published and unpublished data exists that demonstrates the responsiveness of alfalfa to K on Wisconsin soils (Attoe and Truog, 1950; Smith, 1975; Rominger et al., 1976; Smith and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 current UW soil test interpretative ranges (Kelling et al., 1991). However, none of these experiments examined the interactive effect of topdressed K rate, source and timing to determine the most efficient method and manner of K use on alfalfa.

These factors were evaluated as a part of a large experiment at Arlington, WI. The objectives of this combination of experiments were to: 1) determine the economic optimum rate of topdressed K evaluated acrcss various initial soil test K levels; 2) determine if different K sources influenced foraged forage yield or quality; and 3) decide if topdress timing influenced crop performance.

MATERIALS AND METHODS

In early April 1993, selected plots were treated prior to tillage and alfalfa establishment with estimated amounts of sufficient broadcast K to raise soil tests to the midpoint of the desired range. The average resulting soil tests were 69, 75, 85, 126 and 166 ppm soil test K. Following tillage, alfalfa (var. Magnum III) was established by direct-seeding in late April 1993 using Eptam for weed control. The plots were in soybean in 1992. Two harvests were made in the seeding year and three cuttings in each subsequent year. Topdress fertilizer treatments were applied following the late-August cutting in each year so that all cuttings in each the subsequent years would have the different rates in place. Rates used were from 0-350 lb K_2O/a/yr in 70 lb increments. All topdressed K was applied as K_2SO_4 to ensure no salt injury at the highest K rates.

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The K source experiment evaluated the use of K_2SO_4, KCl, or KCl +25 lb S as $CaSO_4$ applied topdress at 3 rates (70, 210 or 350 lb K_2O/a/yr across 2 initial soil test K levels (80 or 135 ppm). The topdress timing experiments evaluated the relative effectiveness of 4 different times of applying topdress K (all after first cut, all after third cut, split between first and third cut, and all in early spring at greenup). A high rate (350 lb K_2O/a/yr) was used as either KCl+S or K_2SO_4 across two soil test K levels (80 or 135 ppm).

Harvests were made using a small plot flail harvester that cuts a 34-inch swath. In general, we attempted to do our harvests at the first-flower stage of growth. A subsample (approximately 500 g wet weight) of the harvested forage was taken for moisture determination and tissue analysis. This tissue was dried at 55 to 60°C and ground to pass through a Wiley mill with a 2-mm screen. Selected samples for each experiment were analyzed for nutrient content by an ICP plasma emission spectrograph at the UW Soil and Plant Analysis Laboratory following the HNO_3-H_2O_2 digestion procedure of Huang and Schulte (1985). Tissue nitrogen levels were determined as a part of the forage quality determination by near-infared scanning (NIRS). Forage quality was assessed using NIRS of the dried tissue at the UW Soil and Forage Analysis Laboratory at Marshfield (Shenk and Westerhaus, 1994). Tissue samples from the first and second cuttings were combined across replications to reduce experiment costs. Similar analyses were performed on individual plot samples for the third cutting. Following third cutting, all plots were soil samples, crown counts taken, and topdressed fertilizer reapplied for the next season. Crown counts were made on two areas per plot, each 2 ft^2. Soil samples were taken to 6 inches by compositing 8 to 10 cores from each plot.

Data were analyzed using ANOVA procedures for the stated design with split plots using the SAS statistical package. Soil test K was the main plot and topdressed K_2O was the split. Regression techniques were employed to evaluate relative responsiveness to soil test levels and K_2O rates.

RESULTS AND DISCUSSION

Topdress Rate

Yield. Table 1 shows the yearly dry matter alfalfa yields for the main effects of soil test K or topdressed K_2O. Only in the last of the individual years was the soil test K by topdressed K_2O interaction term of the ANOVA significant. 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. (1983), Kelling (1984), and Kelling et al. (1995). Interestingly, the addition of topdressed K_2O 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_2O rate. However, in subsequent years, the main effect of topdressed K_2O was significant up to about 210 to 280 lb K_2O/acre/year.

Figure 1 shows the average interaction of soil test K and topdressed K_2O on alfalfa yield. Although the interaction term of the statistical analysis was only significant in 1997, it seems apparent that both factors are contributing to the K nutrition of the plant. Obviously, more topdressed K_2O 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 of greater than 150 ppm, little response to topdressed K_2O was seen. These data also show that if topdressed K_2O 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_2O 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.

Forage Quality. Table 2 shows the average results of the NIRS evaluation of the third cutting for each year for forage quality. Results for the first and second cuttings tended to be similar, however, due to the combining of replicates for these cuts, statistical analysis were not done. These data show a decrease in crude protein content with increasing soil test K levels and topdressed K_2O applied. Since all treatments were applied as K_2SO_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_2O rate. Since stand was not affected by treatment, it is likely that the increased, more rank, growth associated with increasing K treatment resulted in the slight protein depression and increase in fiber.

Tissue Cation Concentrations. Average tissue cation levels for the third cutting forage are provided in Table 3. It is clear that increasing K from either soil test or topdressed K_2O 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_2O were applied irrespective of the initial level present.

At soil tests above 120 ppm soil test K adding more than 160 lb K_2O/a/yr resulted in forage K levels above 3.50% with no increase in yield (Figure 1 and Table 3). 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_2O/a/yr was needed to maximize yield, but these levels did not result in more than 3.5% K in the forage.

Topdress Source

Table 4 shows the average effect of K source on alfalfa yields for each of the four years of the experiment averaged across the rates of topdressed K and initial soil test K levels. These data show that apparently in the first year (1994) the use of KCl caused a slight depression in yield. This effect was most obvious for the second and third cutting, but was not particularly linked to any rate or soil test level. Although we saw a source x timing interaction in the timing experiment (see next section of paper), the time and non-linkage to K rate implies that lower yields may not be directly the result of salt or chloride toxicity. Year 2 (1995) showed no source effects.

In years 3 and 4 of the study, it appears that the addition of sulfur was providing a response in forage yields of about 0.2 to 0.4 T/a of dry matter. Historically, alfalfa has not responded to S additions at Arlington presumably due to the high S release from the soil OM and high precipitation S additions. A recent DNR report, however, shows that the latter have decreased substantially the last 8-10 years. It is also apparent that yields in these years were much lower and that the stand contained substantially more grass. It is not obvious if either of these factors influenced the response or not.

Topdress Time of Application

Table 5 shows the effect of topdress application time for each of the several years of the experiment. In the first two years, where K topdress time had an effect on the results, it appears that there was a detrimental influence from applying the K early in the season and that this detrimental effect was mostly associated with the use of KCl on the first cutting yields (Table 6). There also appeared to be some advantage to splitting this high rate of fertilizer, however, in general, these trends appeared to be quite weak (Pr > F of 0.20-0.30).

Data from these experiments was also used to demonstrate the relative responsiveness of each cutting. Although no clearcut conclusions can be drawn as the data are somewhat mixed, there does appear to be a tendency for a somewhat proportionally larger response to applied fertilizer for the second and third cutting than for the first (data not shown). This is likely due to the need for more rapid nutrient uptake during the summer months when the crop is growing more rapidly.

SUMMARY

These data demonstrate that either soil test K, topdressed K_20, or a combination of both can be used to optimize alfalfa yields. At soil test K levels of 90 to 120 ppm (approximately Wisconsin's current optimum range), about 200 lb K_20/acre/year should be topdressed. 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 K_20/acre/yr appeared to maintain soil test K levels even though removals may have been significantly higher. There is some evidence that use of S may have increased forage yields by 0.2-0.4 T/a during the latter years of the experiment. Time of topdressing application influenced yields modestly in some years with the early spring application (greenup) showing somewhat lower yields if KCl was the fertilizer source.

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Table 1. Main effect of soil test K and topdressed K_2O on alfalfa yields at Arlington, WI, 1994-1997.

Parameter	Yield 1994	1995	1996	1997
	ton/acre (dry weight)			
Soil test K (ppm)				
69	4.24	3.90	3.01	2.28
75	4.37	4.09	2.96	2.33
85	4.29	4.10	3.19	2.32
126	4.64	4.20	2.82	2.27
166	4.52	4.20	2.93	2.50
$LSD_{0.05}$	0.22	0.19	0.14	*
Topdressed K_2O (lb/acre/year)				
0	4.29	3.97	2.59	2.00
70	4.41	4.02	2.96	2.32
140	4.38	3.96	2.98	2.29
210	4.44	4.10	3.11	2.44
280	4.47	4.29	3.08	2.52
350	4.48	4.24	3.18	2.48
$LSD_{0.05}$	NS	0.20	0.15	*

Figure 1. Average interactions of soil test K levels and topdress K_2O rate on alfalfa yields, Arlington, WI, 1994-1997.

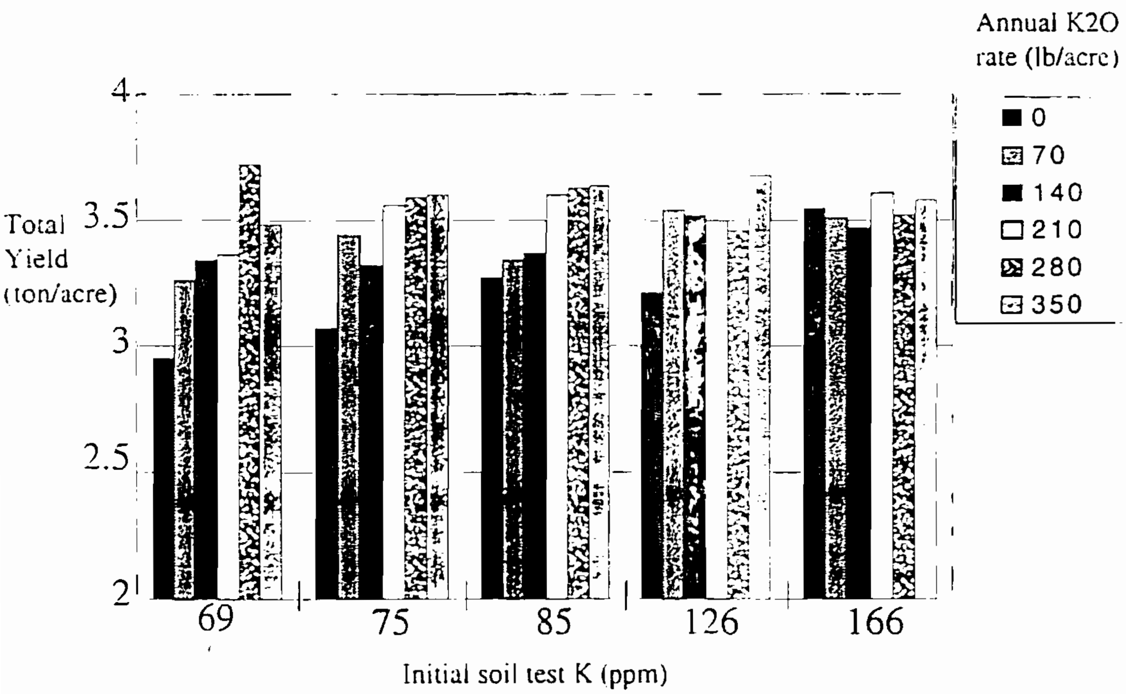

Table 2. Average main effect of soil test K or topdressed K on third cut alfalfa quality at Arlington, WI, 1994-1997.

Parameter		Crude protein	Acid Detergent fiber	Neutral Detergent fiber
		%		
Initial Soil Test K				
(mg/kg)	69	24.1	29.9	40.0
	75	24.1	30.2	40.1
	85	23.6	30.7	41.1
	126	23.4	30.9	40.8
	166	23.3	30.6	40.7
	$LSD_{0.05}$	0.48	1.0	NS
Topdressed K_2O				
(lb/a/yr)	0	23.6	29.7	39.9
	70	23.9	30.0	40.2
	140	23.9	30.2	40.2
	210	23.9	30.6	40.8
	280	23.5	30.9	40.9
	350	23.3	31.3	41.4
	$LSD_{0.05}$	0.48	1.0	NS

Table 4. Average effect of potassium source on yearly alfalfa yields at Arlington, WI, 1994-1997.

K source	Alfalfa yields[1]			
	1994	1995	1996	1997
	(ton/acre (dry weight)			
K_2SO_4	4.63	4.21	2.98	2.39
KCl	4.40	4.16	2.76	1.95
KCl+S	4.29	4.28	2.99	2.40
$LSD_{0.05}$	0.23	NS	0.19	0.19

[1/]Averaged across 3 topdress rates and 2 initial soil test K levels.

Table 3. Effect of initial soil test K level and annual topdressed K_2O treatment on average third cutting forage K, Ca and Mg levels, Arlington, WI, 1994-1997.

Initial soil test K	Topdress K_2O rate	Tissue concentrations K	Ca	Mg
ppm	lb/a/yr		%	
69	0	2.43	1.64	0.50
	70	2.26	1.65	0.48
	140	2.62	1.66	0.45
	210	2.71	1.59	0.44
	280	3.08	1.55	0.41
	350	3.54	1.54	0.41
75	0	2.44	1.69	0.49
	70	2.59	1.74	0.51
	140	2.69	1.67	0.46
	210	2.99	1.66	0.44
	280	3.39	1.57	0.42
	350	3.70	1.53	0.39
85	0	2.58	1.72	0.47
	70	2.90	1.53	0.44
	140	2.99	1.53	0.41
	210	3.19	1.50	0.40
	280	3.36	1.42	0.39
	350	3.75	1.45	0.37
126	0	2.83	1.70	0.45
	70	3.48	1.60	0.41
	140	3.45	1.57	0.41
	210	3.77	1.56	0.40
	280	3.91	1.46	0.36
	350	4.04	1.48	0.36
166	0	3.36	1.57	0.41
	70	3.51	1.55	0.40
	140	3.94	1.52	0.38
	210	4.10	1.52	0.38
	280	3.93	1.47	0.36
	350	3.93	1.44	0.35
Statistical significance (Pr > F)				
Soil test K (ST)		<0.01	<0.01	<0.01
Topdressed K_2O (TD)		<0.01	<0.01	<0.01
ST x TD		0.67	0.70	0.71

Table 5. Average effect of topdress application time on alfalfa yield at Arlington, WI, 1994-1997.

Application time	Yield			
	1994	1995	1996	1997
	ton/acre (dry weight)			
Greenup	4.33	4.16	3.06	2.53
1st cut	4.46	4.35	3.17	2.65
3rd cut	4.48	4.27	3.06	2.47
1st & 3rd	4.44	4.35	3.08	2.61
Pr > F	*	0.20	0.78	0.33

*K source x time interaction significant.

Averaged across two initial soil test K levels and two K sources.

Table 6. Interaction of K source and time on alfalfa yield, Arlington, WI, 1994-1995.

Application time	KCl + S	K_2SO_4
	ton/acre (dry weight)	
Greenup	4.10	4.34
1st cut	4.31	4.48
3rd cut	4.27	4.48
1st & 3rd	4.44	4.34

Averaged across two initial soil test K levels.

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