ALFALFA RESPONSES TO POTASSIUM[1]

K.A. Kelling and R.P. Wolkowski[2]

The potassium 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. Excellent reviews on the role of K in physiological processes are provided in the most recent potassium monograph (Munson, 1985). Potassium also markedly influences alfalfa agronomically through yield increases and improvements in forage quality, disease resistance and over-winter survival. Several recent Wisconsin studies have examined the importance of potassium in alfalfa nutrition.

Crop Responses

Yield (1970 - 1990 Experiments)

A significant amount of published and unpublished data exist that demonstrate the responsiveness of alfalfa to K on Wisconsin soils. Most recently, these experiments have been conducted by Kelling, Peters, Simson, and Wolkowski in the Department of Soil Science or Smith and Collins in the Department of Agronomy at the University of Wisconsin-Madison.

Figure 1 shows data from a set of experiments where soil test K level, as extracted with Bray P_1 extractant, is plotted against yield. These data show that few if any responses to higher soil tests are obtained above about 120 - 140 ppm. These data are not confounded by interactions with topdressed potash since only the untreated controls or residual years of the experiments are plotted. Because of the relatively small number of experiments in this data set, it is not possible to distinguish between soil types; however, there is some tendency toward less response for the high subsoil K red soils (Manitowoc) than the lower subsoil K supplying soils (Lancaster and Hancock).

Other Wisconsin experiments have also helped to identify the soil test K level above which yield response is not observed (Table 1). Even though these experiments generally showed yield responses, the magnitude of some of these responses was quite small: Ashland (112 ppm); Marshfield (78 ppm); and Barron (73 ppm). In other cases, somewhat similar soils responded when at these levels of K.

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[1]Portions of the current research reported in this paper are funded by the Wisconsin Fertilizer Research Council, the Potash Phosphate Institute, Potash Corporation of Saskatchewan, Fluid Fertilizer Foundation, and the College of Agricultural and Life Sciences, UW-Madison.

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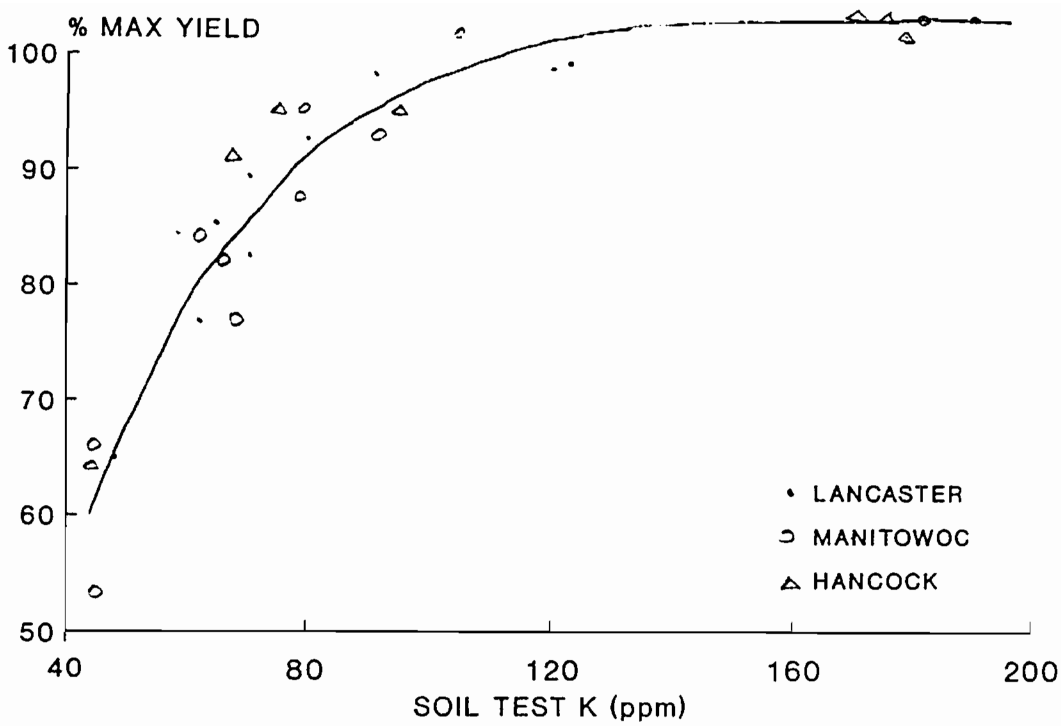

Figure 1. Effect of soil test K on relative alfalfa yield at several Wisconsin locations, 1978-1983. Residual years and unfertilized controls only (Kelling et al., unpublished data).

The data in Table 1 also show that responses to annual topdressed K were generally optimized between 200 and 300 lb K_2O/a especially if soil tests were in the medium range or lower. The data from some specific experiments (Tables 2 and 3) illustrate this more clearly. At Lancaster, responses were seen to the highest level of K_2O applied and the middle level of P_2O_5, whereas at Arlington, responses were seen to about 720 lb K_2O/a/yr. Initial soil test K levels were 85 ppm at Lancaster and 63 ppm at Arlington. At both locations the response curve shows a rather large initial increase and then gradual, but continual, increases thereafter. This type of curve means that the most profitable rate is likely to be sensitive to fertilizer costs and the value placed on the hay. When hay is very highly valued, such as in 1988, it would be more profitable to fertilize at a higher rate; however, in other years such as 1990 - 1991, when hay value is much lower, a more modest application is most profitable. Note that at Arlington (Table 3), although yields continued to increase to 720 lb K_2O/a/yr, the most profitable rate is much more modest except when the very highest value is put on the hay. These data also mean that irrespective of the costs or hay value, when soil tests are in the medium range or below, some topdressed potash is essential and highly profitable.

Table 1. *Alfalfa yield responses to applied K_2O from several Wisconsin experiments.*

	Study*																
	15	16	16	17	26	7	7	7	7	**	**	**	1	1	27	24	4
Site years	1	4	6	2	6	5	5	2	3	1	2	1	10	10	2	3	2
lb K_2O/yr	Yield, T/A DM																
0	3.65	3.21	2.60	3.69	2.88	3.60	3.44	2.46	3.92	3.13	2.98	3.01	2.61	2.03	2.66	3.93	2.88
50-100					3.73					3.68		3.20	3.26	2.38			
101-200			3.89		4.01	4.46	3.99	2.42		3.64	3.41	3.36	3.69	2.76	3.51		2.96
201-300	3.81	4.01	4.30		4.24	4.85	4.11	2.60	4.27	3.74	4.16		3.72	3.05		4.27	2.96
301-400				4.85						3.69						4.27	
>400		4.14		4.75	4.41	5.20	4.27	2.64	4.23			3.38			3.50		3.08
Soil test (ppm)	64	L	VL	62	62	86	81	112	80	80	118	79	50	50	60	78	73
Location***	Arl	Arl	Han	Arl	Arl	Lan	Man	Ash	Msh	Msh	Sheb	Ash	Bar	Bar	Arl	Msh	Bar

* Study numbers refer to the reference numbers in the Literature Cited section of this paper.

** Unpublished data of R.D. Powell or D. Smith, Department of Soil Science or Agronomy, respectively, Univ. of Wisconsin-Madison.

*** Locations include Arlington (Arl), Hancock (Han), Lancaster (Lan), Manitowoc (Man), Ashland (Ash), Marshfield (Msh), Sheboygan (Sheb), and Barron (Bar).

Table 2. Yield response to annual P and K topdressing at Lancaster, 1978-1983.*

K_2O applied	P_2O_5 level (lb/a/yr)		
	0	57	114
lb/a/yr	----------Yield, T/a DM ---------		
0	3.56	3.60	3.57
120	4.40	4.46	4.62
240	4.63	4.05	4.96
480	4.85	5.20	5.17
720	5.12	5.22	5.20

*Adapted from Kelling (1984). Fertilizer added in split applications 1978-1981; field was reseeded in 1980 and are not included in data set.

Table 3. Effect of topdressed KCl on the yield of alfalfa and return above fertilizer cost at Arlington, 1970-1972.*

K_2O applied lb/a	Avg. yield** T/D.M.	DM hay price $/T		
		60	100	140
		$ return above fertilizer cost***		
0	2.88	172.80	288.00	403.20
60	3.53	204.60	345.80	487.00
120	3.73	209.40	358.60	507.80
240	4.00	211.20	371.20	531.20
480	4.23	196.20	365.40	534.60
720	4.41	178.20	354.60	531.00
960	4.31	143.40	315.80	488.20

* Adapted from Smith (1975). Fertilizer applied in fall 1969 and 1970; initial soil test K = 63 ppm.

** Responses were similar; data are averaged for three- and four-cut systems.

*** Fertilizer cost set at $0.12/lb K_2O

Verification Experiments (1991 - present)

In response to the data such as those cited previously in this paper the University of Wisconsin revised the soil test recommendation program in 1990. The result is that the new program establishes optimum soil tests at a somewhat lower level such that the combination of what is provided by the soil plus what is added as topdressed fertilizer optimizes yield. This approach, although strongly supported by research data, has been questioned by some farmers and agribusiness representatives (Beck, 1991; Reetz, 1991).

In an attempt to evaluate the relative merits of these programs, a series of experiments was established at 11 locations across Wisconsin with the specific objective of determining whether the new or the former soil test recommendation program provided the greatest economic return to the farmer. Treatments used at each of the locations were: 1) an untreated control; 2) phosphate and potash as recommended by the 1990 recommendation program; 3) phosphate and potash as recommended by the 1981 recommendation program; 4) the new program P and K plus 25 lb S/a and 1 lb B/a; and 5) the old program P and K plus sulfur and boron. At three locations a treatment containing a local dealer's manufactured material was also used. The exact rate of P_2O_5 or K_2O fertilizer application varied between locations and was based on the initial soil tests (Table 4). Sources of nutrients were: phosphate, 0-46-0; potash, 0-0-60; sulfur, calcium sulfate; and boron, borate 48. Treatments were re-applied following third cut each year.

Table 5 shows the total yields for 1991 and 1992 and the stand counts following third cut each year. Plots located in northern Wisconsin where they were harvested by experiment station personnel have not yet been summarized for 1992. In 1991 no yield responses were observed except at Hancock. This was somewhat surprising in that some response was expected at those sites testing in the optimum range or lower (Marshfield, Ashland, Eden and Lancaster). The yields are quite average at all of these locations and perhaps in a better growing season responses would have been observed. Conditions at Ashland and Marshfield were wet and at Lancaster they were relatively dry especially during the latter part of the summer.

In 1992, as in 1991, some individual cuttings showed statistically significant differences, however these trends did not remain consistent throughout the year. In general, the probability values associated with yields even where responses would be expected were in the 0.20 to 0.30 range. Other alfalfa research has shown larger treatment response differences with successive years of cropping and fertilization (Gerwig and Ahlgren, 1958; Erickson et al., 1981). In these kinds of experiments yields from the check and the lower treatment levels tend to become smaller, whereas where higher are used, yields rates tend to be maintained.

Samples from this verification study were analyzed for forage quality using near infra-red analysis. At the lowest testing site (Eden) there was a clear tendency for improved ADF, NDF and CP with topdressed additions compared to the check, but no obvious difference between the various topdress treatments (data not shown).

Stand Survival

Although the data from the verification experiment up to this point in time do not confirm the trend, there are many examples of Wisconsin experiments which show the strong relationship between increased alfalfa persistence and potassium fertilization (Wang et al., 1953; Smith and Powell, 1979; Jung and Smith, 1959; and Kelling, 1984). Examples of this relationship are shown in Table 6. Although the exact mechanism of this influence has not been pinpointed, several factors including the influence of K on increasing starch and sugar levels, depressing the plant freezing point, increasing plant regrowth rate, increasing root xylem size and distribution, and improving disease resistance have been suggested.

Several Wisconsin experiments also provide insight as to the soil test K level which appears to be adequate for maintaining alfalfa stands. From these

Table 4. Initial soil tests and P and K treatment rates for the alfalfa soil test recommendation verification plots at several Wisconsin locations, 1991.

Location	Soil series	pH	OM	Initial soil test and interpretation* P	Initial soil test and interpretation* K	1990 Recom. P_2O_5	1990 Recom. K_2O	1981 Recom. P_2O_5	1981 Recom. K_2O
			%	ppm	ppm	lb/a	lb/a	lb/a	lb/a
Hancock	Plainfield	6.2	0.8	56 H	149 H	30	250	65	260
Marshfield	Withee	6.1	2.4	47 EH	104 L	0	200	0	307
River Falls	Pillot/Jenett	6.8	2.4	40 EH	153 H	0	0	0	200
Spooner	Pence	6.9	1.4	90 EH	185 VH	0	100	0	213
Ashland	Outagamie	6.9	2.7	48 EH	97 O	0	40	0	150
Oakfield	Lomira	6.6	1.5	69 EH	137 H	0	125	0	250
Ashford	Dodge	6.2	1.5	25 H	142 H	30	125	65	250
Eden	Fox	7.3	2.5	28 H	75 L	30	265	65	356
Lancaster	Fayette	6.9	2.4	42 EH	115 O	0	250	30	290
Arlington Soils	Plano	6.6	3.4	202 EH	245 EH	0	0	0	250
Arlington Beef	Plano	7.1	4.0	36 H	189 VH	65	125	88	250

* Interpretations based on 1990 recommendation program.

Table 5. Effect of fertility recommendation program on alfalfa yield and stands at several Wisconsin locations, 1991 and 1992.

Treatment	1991 Yield	1991 Stand	1992 Yield	1992 Stand	1992 soil test* P	1992 soil test* K
	T/a	plt/ft^2	T/a	plt/ft^2	------ ppm	------
Arlington Soils						
Check	4.38	5.6	4.42	4.2	188	185
New	4.25	5.3	4.40	3.7	185	200
Old	4.58	5.2	4.48	3.6	180	305
New + SB	4.58	5.6	4.76	4.1	190	178
Old + SB	4.50	5.7	4.77	4.2	188	289
$LSD_{0.05}$	NS	NS	NS	NS	NS	75
Pr > F	0.13	0.85	0.35	0.38	0.70	0.01
Arlington Beef						
Check	4.09	5.8	4.21	3.9	23	145
New	4.01	5.8	4.17	2.9	28	184
Old	4.03	4.8	4.15	2.8	33	238
New + SB	4.06	5.5	4.30	3.1	30	184
Old + SB	4.06	5.9	4.06	3.1	34	215
$LSD_{0.05}$	NS	0.98	NS	NS	10	39
Pr > F	0.99	0.16	0.77	0.24	0.16	0.00
Lancaster						
Check	3.61	4.1	3.77	3.4	26	111
New	3.54	4.5	3.82	3.9	27	176
Old	3.56	3.7	3.91	3.9	31	188
New + SB	3.53	4.8	3.59	3.3	30	181
Old + SB	3.66	4.0	3.85	3.2	31	183
$LSD_{0.05}$	NS	0.91	NS	NS	NS	57
Pr > F	0.93	0.14	0.50	0.26	0.41	0.06
Hancock						
Check	3.17	4.33	2.05	1.6	40	79
New	3.11	4.92	2.29	2.1	48	164
Old	3.71	6.25	2.28	2.2	60	166
New + SB	3.48	5.33	2.55	2.6	50	145
Old + SB	3.66	6.08	2.34	1.8	56	136
$LSD_{0.05}$	0.44	1.40	NS	NS	8	33
Pr > F	0.04	0.06	0.23	0.65	0.00	0.00
Marshfield						
Check	2.74	4.50	Data not analyzed			
New	3.07	4.11				
Old	2.82	5.78				
New + SB	3.10	5.50				
Old + SB	2.92	6.50				
$LSD_{0.05}$	NS	1.9				
Pr > F	0.16	0.09				
Spooner						
Check	2.34	4.50	Data not analyzed			
New	2.39	4.62				
Old	2.30	4.38				
New + SB	2.25	5.00				
Old + SB	2.47	4.50				
$LSD_{0.05}$	0.15	NS				
Pr > F	0.05	0.98				

Table 5. (Continued)

Treatment	1991 Yield	1991 Stand	1992 Yield	1992 Stand	1992 soil test* P	1992 soil test* K
River Falls						
Check	3.87	9.7	Data not analyzed			
New	3.77	10.2				
Old	3.89	11.1				
New + SB	3.84	8.9				
Old + SB	3.92	10.7				
$LSD_{0.05}$	NS	NS				
Pr > F	0.95	0.87				
Ashland						
Check	2.54	5.7	Plots abandoned			
New	2.66	6.4				
Old	2.61	5.9				
New + SB	2.46	5.5				
Old + SB	2.72	5.9				
$LSD_{0.05}$	NS	NS				
Pr > F	0.79	0.84				
Oakfield						
Check	4.07	6.7	3.75	3.9	56	95
New	4.18	6.4	3.44	3.1	62	124
Old	4.05	6.2	3.61	3.7	53	148
New + SB	4.03	6.1	3.57	3.5	63	134
Old + SB	4.06	6.5	3.46	3.4	62	156
Manuf.	4.11	5.8	3.22	2.7	72	156
$LSD_{0.05}$	NS	NS	NS	NS	NS	47
Pr > F	0.97	0.74	0.74	0.63	0.40	0.05
Ashford						
Check	3.00	6.0	4.19	5.2	18	86
New	3.07	5.3	4.10	5.4	22	121
Old	3.17	6.4	4.38	5.4	24	139
New + SB	3.25	5.8	4.44	5.2	25	113
Old + SB	3.32	6.2	4.42	4.9	28	164
Manuf.	3.01	5.7	4.26	5.4	23	124
$LSD_{0.05}$	NS	NS	0.31	NS	NS	34
Pr > F	0.34	0.57	0.20	0.91	0.23	0.01
Eden						
Check	4.68	5.8	Data not analyzed			
New	4.69	5.9				
Old	4.71	6.1				
New + SB	4.93	6.0				
Old + SB	4.21	6.6				
Manuf.	4.49	5.6				
$LSD_{0.05}$	NS	NS				
Pr > F	0.09	0.85				

*Stand counts and soil samples taken following third cutting each year.

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Table 6. Effect of K fertilization and soil test K on alfalfa stand survival at several Wisconsin locations.

K_2O Tmt	Lancaster (3)*		Manitowoc (7)*		Barron (3)*		Arlington (4)+		Madison (6) =	
	soil K	% stand	soil K	% stand	soil K	% stand	soil K	% stand	soil K	% stand
lb/a/yr	ppm	%	ppm	%	ppm	%	ppm	%	ppm	%
0	55	33	65	35	51	19	83	35	94	50
60	--	--	--	--	--	--	85	50	--	--
120	59	54	74	42	62	33	90	67	--	--
240	68	62	88	48	75	48	92	76	--	--
480	118	71	168	51	119	55	109	86	197	71
720	190	73	275	54	171	65	145	89	511	69
960	--	--	--	--	--	--	228	90	--	--
1200	--	--	--	--	--	--	--	--	462	72

*Adapted from Kelling, 1984; number in ( ) is the number of winters.

+Adapted from Smith, 1975; average of 3 and 4 cut systems.

=Adapted fropm Rominger et al., 1976.

experiments it would appear that maintaining soil test K at about 100-120 ppm is adequate for most soils. These results are similar to the New Jersey results of Markus and Battle (1965) where they showed that 107 ppm soil test K was adequate for stand survival (17, 34, 55, 59 and 66% survival after 3 years with soil tests of 47, 82, 107, 243, 295 ppm soil test K, respectively). Although somewhat higher levels were slightly more advantageous in some situations, in most cases it likely is not economically advisable to maintain soil tests at these elevated levels.

Compaction Interactions

In perennial crops, such as alfalfa, compaction problems may pre-exist stand establishment or develop after seeding because the soil is subjected to many traffic passes (annual topdressing, cutting, raking, and baling or chopping). In the latter case, yield and stand loss may also be caused by physical damage to the alfalfa crown from wheel traffic. Researchers in California (Rechel et al., 1991) have shown yield reductions in alfalfa related to both situations.

Research conducted on corn in Wisconsin has demonstrated the importance of maintaining K fertility on compacted soils (Wolkowski et al., 1987). It is suspected that K fertilization improved rooting and therefore enhanced nutrient and water uptake. Because alfalfa has a relatively high K requirement, it is likely that a relationship also exists between compaction and K fertility for this crop.

Plots were established at the Arlington Agricultural Research Station on a Plano silt loam. In 1991, treatments were established in a split plot treatment arrangement with compaction as the main plot treatment (none or a 2X wheel-tracking with a 14 T payloader prior to seeding) and soil test K as the subplot (indigenous [90 ppm], 150 ppm, and 225 ppm). Sub-subplot treatments are none, 150- or 300 lb/a K_2O broadcast and 75, 150 or 300 lb/a K_2O banded. These treatments were not applied in 1991 because of stand establishment problems.

Table 7 shows the main treatment effect on total yield for 1991 and 1992. It is clear that compaction had a significant influence on yield in both years. When the data are examined on an individual cutting basis, they show the compaction effect was not significant for the second cutting in 1991 but was a significant influence for all other harvests. The data also show a tendency for yield response to soil test K, but this is much more obvious at the high compaction level as evidenced by the significant interaction term in 1992. Data showing this interaction relationship are given in Figure 2. The annual treatments have not resulted in yield responses to this point in time.

Summary

A total fertility program for forages is essential to ensure a continuous supply of high yielding, high quality feed. Central to the total program is the application of topdressing fertilizer throughout the life of the stand where it is needed. Based on this Wisconsin data we are confident that the Wisconsin recommendations that use the concept of combining soil available

Table 7. Main effects of compaction, soil test K and annual K treatments on yields alfalfa yield at Arlington, WI, 1991-1992.

Main effect	1991 Yield	1992 Yield
	T/a	
Compaction		
< 5 T	2.27	4.13
14 T	1.30	3.32
Soil K (1992 values) (ppm)		
117	1.73	3.65
142	1.82	3.72
179	1.79	3.80
Annual K tmt (lb K_2O/a)		
0	--	3.64
75 band	--	3.72
150 band	--	3.76
300 band	--	3.66
150 bdcst	--	3.77
300 bdcst	--	3.80
<u>Significance</u> (Pr > F)		
Compaction (C)	0.01	0.01
Soil K (S)	0.18	0.13
Annual K (A)	--	0.59
C x S	0.34	0.55
C x A	--	0.25
S x A	--	0.08
C x S x A		0.40

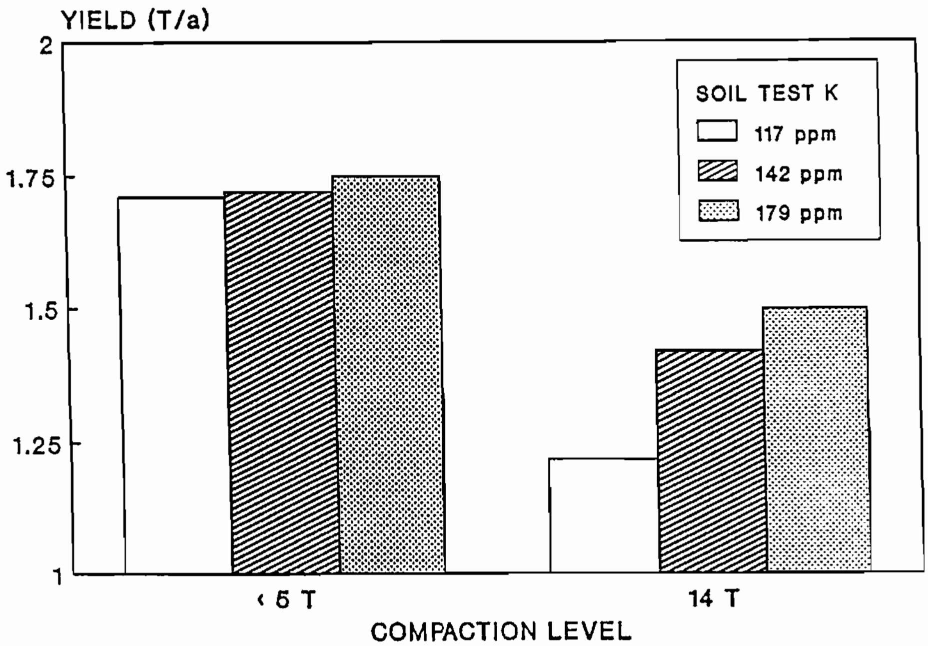

Figure 2. Interaction of compaction and soil test K on yield of first cut, Arlington, 1992 (Pr > F = 0.03).

nutrients with annual topdress programs are appropriate for Wisconsin farmers. Few yield responses are seen above K levels of 100-120 ppm K and neither stand survival nor forage quality appear to be enhanced above this level. Where soils are severely compacted responses to higher K levels may be possible. These data also emphasize that the addition of topdressed nutrients is essential when soil tests are in the optimum range or below. At higher soil test levels, these additions appear to be more optional.

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PROCEEDINGS OF THE TWENTY-SECOND

NORTH CENTRAL EXTENSION - INDUSTRY

SOIL FERTILITY CONFERENCE

November 18-19, 1992, Holiday Inn St. Louis Airport

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Volume 8

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