EFFECT OF SOIL pH AND ALFALFA STAND DENSITY ON ALFALFA NITROGEN CREDITS [1/]

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Introduction

Although plant genetics and cutting management are most likely the primary factors affecting alfalfa persistence, proper fertility management can significantly improve winter survival in several ways. High fertility results in increased root branching and extension, increased growth rate after winter, increased stored food reserves, lowered cell freezing point, and increased disease resistance. Soil pH has been shown to be a significant factor in influencing stand persistence. Considerable research has been conducted that illustrates the importance of fertilization on stand survival under Wisconsin conditions. Specific studies that illustrate the substantial decrease in stand survival associated with more acid soils include Wang et al. (1953), Kelling et al. (1982), Peters and Kelling (1988), Kelling and Wolkowski (1991), and Kelling et al. (1998a). These data from several locations showed that stand survival was strongly linked to pH and that the pH necessary for optimum survival was at least 6.4, and often 6.7, or above.

In addition, research has also shown that a full stand of alfalfa contains all of the nitrogen needed by a succeeding corn crop (Hesterman et al., 1987; Fox and Piekielek, 1988; Bundy and Andraski, 1993). Furthermore, it has been shown that differences in alfalfa stand density affect N credits to corn due to differences in total plowdown N yield of the forage (Higgs et al., 1976; Voss and Shrader, 1984; Kelling et al., 1992). These studies observed that less fertilizer N is needed to maximize corn yield following better stands than is needed following poorer stands. In general, Wisconsin's and other states' N crediting recommendations reflect these observations.

Other factors that affect crop growth may complicate the alfalfa N credit relationship. For example, several Wisconsin experiments have shown that pH can significantly increase corn yield up to a pH of about 6.0 (Powell, 1975; Schulte et al., 1981).

In both 1997 and 2002, existing alfalfa stands on the pH plots at Hancock, Marshfield (2002 only) and Spooner showed significant variation in stand density primarily due to the established pH differences. This provided the opportunity to examine the interactive effects of pH and alfalfa stand on the responsiveness of corn to nitrogen fertilizer.

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Methods and Materials

In the spring of 1997 at Hancock and Spooner and 2002 at Hancock, Marshfield, and Spooner, the pH plots at these locations were sprayed with glyphosate, plowed and planted to corn. Due to the variation in established pH levels, varying alfalfa stand densities from almost zero to nearly a full stand existed at the time of plowing. These plots had soil pH levels ranging from about 4.7 to slightly more than 7.0 at each of the locations. These large plots were matched by actual pH levels to the extent possible and then subdivided into eight sidedress N rates (0, 30, 60, 90, 120, 150, 180, and 210lb N/acre) to give the following experimental designs: pH^8 x N $rate^8$ x rep^2 at Hancock, pH^6 x N $rate^6$ x rep^2 at Marshfield, and pH^5 x N $rate^8$ x rep^2 at Spooner. The nitrogen was sidedressed as ammonium nitrate prior to cultivation.

All plots at each location received 100 lb/acre 5-20-30 as starter and pest management and irrigation as practiced on the experimental farm.

Silage was harvested by cutting all plants in a 10-ft random section out of row 2 from each subplot. A subsample of approximately 800 g (wet weight) was used for moisture determination and tissue analysis. Results of the tissue analysis are not yet complete. Grain was harvested by plot combining rows 3 and 4 (30 ft harvested length from each row). Yields are reported as dry matter for silage and adjusted to 15.5% moisture for grain.

Results and Discussion

Results showing the influence of pH on the stand evaluations are provided in Table 1. It is clear that pH influenced stand survival and that stand survival was maximized at a pH of about 6.4 at both locations in 1997 and about the same level or a little higher in 2002. As has been shown by many previous studies, if alfalfa is to survive and produce, growers must adhere to an aggressive liming program. However, because pH was so directly linked to stand survival, this study may be somewhat restricted in its ability to separate the pH and the alfalfa N supplying influences.

The 1997 effect of alfalfa stand density on legume N credit was reported by Kelling et al. (1998b). However, since this experiment was repeated using essentially the same design, some results will again be presented here. At both Hancock and Spooner in 1997, a pH of at least 5.5 to 5.7 was necessary to achieve top yields. Similarly in 2002, top yields at none of the locations were attained at the lowest soil pH level or two irrespective of how much fertilizer nitrogen was applied. This would seem to indicate that the low pH is creating some limiting factor for the corn beyond the influence on stand density and, therefore, nitrogen supplying capacity.

In 1997, as pH and stand density increased, the response to applied N was smaller. For example, at Hancock at pH 4.8 and associated stand density of about 20%, 150 to 180 lb N/acre was needed to maximize grain yields, whereas at a pH of 6.1 (about 60% stand) this was achieved at 90 lb N/acre. At Spooner, the first N rates to achieve 120 bu/acre of N were 150 lb/acre at pH 4.7 (20% stand), 120 lb N/acre at pH 5.7 (58% stand), 60 lb/acre at pH 6.8 (50% stand), and 0 lb N/acre at pH 6.9 (60%

stand). In 2002, it appears that the highest N rate was needed at Hancock to reach the highest yields (>9.5 T/acre silage yield and >200 bu/acre grain yield). And although the lowest pH level never reached these yields, the shape of the response curve remained similar across all of the stand densities (30 to 70%). These results may be due to excessive leaching of N that occurred on 21-22 June 2002 when almost 10 inches of rain fell during a 2-day span.

The results from both Marshfield and Spooner in 2002 were much more typical in that at least 150 lb N/acre was needed for highest yields at the lowest pH (2% stand at Marshfield and 6% stand at Spooner), whereas only 60 to 90 lb N/acre was needed when the stand was 59% at Marshfield and 27% at Spooner. At the highest soil pH (70% stand at Marshfield and 93% at Spooner), top silage yields were achieved with 30 to 60 lb N/acre. Grain yields appeared to respond to a higher N rate at both sites.

In 1997, we were able to create multiple-regression response surfaces that included visual % stand and N rate as independent variables and yield as the dependent variable. These results showed that the magnitude of the decline of the optimum N rate with increasing stand density is almost exactly that recommended in the current system being used in Wisconsin. Similar evaluations will be conducted on the 2002 data and will include examination of silage yields and nitrogen uptake by these same tech-niques.

Summary

This study confirms that the current UW system for estimating fertilizer nitrogen replacement value for alfalfa is supportable by field research. Credits are substantial even on very sandy soils and are closely linked to stand density. Ignoring or significantly discounting the fertilizer N replacement value for legumes is an economically and environmentally expensive choice.

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Table 1. Effect of pH on third- or fourth-year alfalfa stands at three Wisconsin locations. †

Target pH	Hancock Actual pH	Hancock Stand estimate	Marshfield Actual pH	Marshfield Stand estimate	Spooner Actual pH	Spooner Stand estimate
		%		%		%
			1997			
4.5 to 4.8	4.8	21	—	—	4.7	20
5.0 to 5.3	5.0	22	—	—	5.2	54
5.5 to 5.8	5.3	36	—	—	5.7	58
6.0 to 6.3	5.7	63	—	—	6.8	50
6.5 to 6.8	6.1	70	—	—	6.9	60
7.0 to 7.3	6.7	71	—	—	—	—
			2001			
4.5 to 4.8	5.7	20	4.2	2	4.8	6
5.0 to 5.3	6.0	30	4.9	7	5.2	26
5.5 to 5.8	6.0	46	5.8	59	5.8	27
6.0 to 6.3	6.3	68	6.5	59	6.2	86
6.5 to 6.8	6.4	67	6.9	67	6.7	93
7.0 to 7.3	6.8	76	7.1	70	—	—

† Each stand was in its third or fourth year of alfalfa. The two crops were separated by a year of corn.

Table 2. Effect of pH (and estimated alfalfa stand) on corn silage and grain yield response to N fertilizer at Hancock, 2002.

N Rate	pH (% stand) 5.73 (20)	5.94 (30)	6.03 (46)	6.26 (70)	6.29 (66)	6.42 (67)	6.65 (79)	6.80 (72)	Avg
lb/acre									
				Silage yield (ton/acre dry matter)					
0	6.2	5.2	5.4	6.6	5.5	5.4	6.2	5.9	5.80
30	5.4	7.3	7.4	6.9	6.2	7.5	7.2	7.5	6.92
60	8.5	7.1	8.4	6.5	7.9	7.0	6.6	7.1	7.39
90	8.3	7.3	6.8	7.7	6.7	8.0	7.1	7.4	7.41
120	6.5	9.3	8.1	7.9	8.7	8.3	8.1	7.1	8.00
150	6.9	9.3	7.8	8.9	8.7	7.8	8.2	6.7	8.04
180	8.3	8.9	8.1	9.5	7.6	8.3	8.3	8.2	8.40
210	7.6	10.0	10.0	9.5	9.3	9.5	7.7	8.8	9.05
Average	7.21	8.05	7.75	7.94	7.57	7.72	7.42	7.34	
				Grain yield (bushels/acre)					
0	147	111	125	119	119	124	128	128	125
30	134	152	140	136	130	145	151	134	140
60	168	156	164	133	169	166	154	155	158
90	164	164	145	163	151	163	150	157	157
120	158	180	170	186	166	168	162	181	171

150	161	188	149	180	164	181	179	159	170
180	188	190	184	159	183	171	172	180	178
210	166	204	200	197	188	205	200	198	195
Average	161	168	160	159	159	165	162	162	

Table 3. Effect of pH (and estimated alfalfa stand) on corn silage and grain yield response to N fertilizer at Marshfield, 2002.

	pH (% stand)						
N Rate	4.25(2)	4.89(7)	5.83 (59)	6.48 (59)	6.95 (67)	7.11(70)	Avg
lb/acre							
			Silage yield (ton/acre dry matter)				
0	4.6	5.9	6.6	5.9	7.0	6.5	6.08
30	5.3	6.5	6.1	6.8	6.9	7.5	6.52
60	6.7	6.9	7.0	6.6	8.5	8.4	7.35
90	6.7	6.6	7.5	8.4	8.6	7.3	7.52
120	6.5	7.8	8.2	8.4	8.6	8.1	7.93
150	7.7	7.4	7.9	8.1	8.1	7.7	7.82
Average	6.25	6.85	7.22	7.37	7.95	7.58	
			Grain yield (bushels/acre)				
0	73	90	90	107	119	129	101
30	115	123	121	131	136	153	130
60	121	140	143	138	153	149	141
90	143	132	149	161	159	158	150
120	137	149	150	170	169	157	155
150	140	140	152	157	167	175	155
Average	122	129	134	144	151	154	

Table 4. Effect of pH (and estimated alfalfa stand) on corn silage and grain yield response to N fertilizer at Spooner, 2002.

	pH (% stand)					
N rate	4.8(6)	5.2(26)	5.8 (27)	6.2 (86)	6.7(93)	Avg.
lb/acre						
			Silage yield (ton/acre dry matter)			
0	4.3	6.5	7.1	7.5	6.3	6.34
30	6.0	6.8	7.2	7.2	8.3	7.10
60	5.0	9.2	8.7	7.4	8.4	7.74
90	7.2	5.9	7.9	7.6	8.3	7.38
120	3.8	9.7	8.2	8.7	7.3	7.54
150	5.4	7.5	7.6	11.0	8.3	7.96
180	6.6	7.1	8.3	7.9	8.5	7.68
210	4.7	7.1	7.7	7.6	8.6	7.14
Average	5.38	8.21	7.84	8.11	8.00	
			Grain yield (bushels/acre)			
0	93	145	130	135	149	130
30	102	151	177	127	136	139
60	116	159	158	171	155	152
90	126	151	168	143	156	149
120	128	181	166	173	144	158
150	136	139	163	188	163	158
180	116	134	161	186	184	156
210	118	172	174	157	176	159

Average	117	154	162	160	158