SENSITIVITY OF SEVERAL SPECIES OF GRASSES AND LEGUMES TO SOIL ACIDITY

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The relative tolerance of timothy, red fescue, bromegrass, Kentucky bluegrass, Russian wild ryegrass, alsike clover, red clover, alfalfa, and birdsfoot trefoil to soil acidity was determined under field conditions by measuring forage and seed yields on three limed and nonlimed strongly to very strongly acid soils (*p*H 4.1–5.1). Relative tolerance among species varied considerably from soil to soil, presumably because of the wide variation found in content of plant-available Al and Mn. The grasses, in general, were more tolerant than the legumes, except that Russian wild ryegrass was extremely sensitive to acidity on one site. Without lime the highest yield of forage was obtained from timothy or bromegrass, and the highest yield of seed from red fescue. Red clover produced more forage than alsike clover on two of the three acid soils, and produced the greatest yield of seed of any legume.

La tolérance relative de la fléole des prés, de la fétuque rouge, du brome, du paturin de Kentucky, de l'elyme de Russie, du trèfle d'alsike, du trèfle rouge, de la luzerne, et du lotier corniculé à l'acidité a été déterminée sur le terrain, d'après le rendement de fourrage et de semence. L'étude portait sur trois sols acides à très acides, avec ou sans chaux (*p*H 4.1–5.1). La tolérance relative des espèces varie considérablement d'un sol à l'autre, par suite sans doute de la grande variation constatée dans les teneurs d'aluminium et de manganèse disponibles aux plantes. En général, les graminées montrent plus de tolérance que les légumineuses, sauf l'élyme de Russie qui, dans l'un des sols, s'est montrée extrêmement sensible à l'acidité. Sans chaulage, le plus grand rendement de fourrage a été obtenu avec la fléole ou le brome, et le meilleur rendement de semence avec la fétuque rouge. Le trèfle rouge a donné plus de fourrage que le trèfle d'alsike dans deux des trois sols acides, et a produit plus de semence que les autres légumineuses.

INTRODUCTION

There are approximately 200,000 ha of strongly to very strongly acid soils under cultivation in the Peace River region of Alberta and British Columbia. Successful cropping of such soils can be achieved either by liming or by the use of species that are relatively tolerant to soil acidity. Farmers in the region have made little use of lime because it is expensive and not readily available. Consequently, the use of acidity-tolerant species is especially important.

It is well known that crop species vary greatly in their tolerance to soil acidity (Jackson 1967). The primary objective of the work reported in this paper was to determine the relative tolerance to soil acidity of several species of grasses and legumes under field conditions, and to find the most productive species for use on very acid soils in the Peace River region.

MATERIALS AND METHODS

Experiments were conducted on three different soils at widely separated sites (Table 1). Experiments were of a split-plot design with four replicates. Main plots consisted of (1) no lime, and (2) lime (calcium hydroxide) mixed into the top 15 cm of soil at a rate estimated to bring soil to *p*H 6.5. The lime applications were made late in the fall of 1964.

Subplots, 2.4 × 6.1 m in size, consisted of the following species and cultivars seeded in the spring of 1965. Grasses: timothy, *Phleum pratense* L. cult Climax; red fescue, *Festuca rubra* L. cult Olds; bromegrass, *Bromus inermis* Leyss. cult Carlton; Kentucky bluegrass, *Poa pratensis* L. cult Park (sites 1 and 2); and Russian wild ryegrass, *Elymus junceus* Fisch. cult Sawki (site 3 only); and legumes: alsike clover, *Trifolium hybridum* L. cult Aurora; red clover, *Trifolium pratense* L. cult Altaswede; alfalfa, *Medicago sativa* L. cult Beaver; and birdsfoot trefoil, *Lotus corniculatus* L. cult Leo.

Fertilizer materials were mixed into the plow layer at seeding time to suply N, P, K, S, Ca, and Mg at rates of 90, 24, 50, 14, 60, and 7 kg/ha, respectively. Fertilizer materials were NH_4NO_3, triple superphosphate, K_2SO_4, $CaCl_2$, and $MgCl_2$. Additional fertilizers were top dressed in the early spring of 1966 and 1967 to give annual applications of N, P, K, and S at rates of 56, 34, 34, and 14 kg/ha, respectively. The applications of N in 1966 and 1967 were made only to the grasses and not to the legumes.

Yields of dry matter were determined for each site by taking single cuts of forage from portions of each subplot in July of 1966 and 1967. The remainder of each subplot was harvested for seed yield at maturity at sites 1 and 2.

Analyses for *p*H, exchangeable Al, and soluble Mn were made on soil samples taken in July 1967 to a depth of 120 cm at the three sites from limed and nonlimed treatments. Soil *p*H was determined in a 1:2.5 soil:water mixture. Exchangeable Al was extracted in 2 min from the soil with 1 N KCl and soluble Mn was extracted in 16 h of shaking in 0.01 M $CaCl_2$. These methods have been found to give good estimates of plant-available Al and Mn (Hoyt and Nyborg 1971*a, b*).

RESULTS

Soil Analyses

Interpretation of results of the field experiments requires consideration of some chemical characteristics of soils at the three sites. Soil *p*H of the 0–15-cm depth was 5.1, 4.5, and 4.1 for nonlimed treatments at sites 1, 2, and 3, respectively, whereas *p*H of limed treatments was 6.1, 6.0, and 5.6, respectively (Table 1). Soil *p*H of the 15–30-cm depth was increased by only 0.1 and 0.2 when limed at sites 1 and 2, respectively, and was decreased by 0.1 at site 3. Because the soil samples were taken 3 yr after the lime was applied, these results show that there was little downward movement of lime. At all sites, soil acidity increased with depth to 45 cm or more.

Nonlimed topsoils at the three sites were different not only in *p*H, but also in content of Al and Mn. Exchangeable-Al and soluble-Mn contents at site 1 were 42 and 32 ppm,

Table 1. Soil characteristics of limed and nonlimed treatments 3 yr after application of lime

	Site 1. Dawson Creek, B.C. Gray Luvisol–Alcan series			Site 2. Spirit River, Alberta. Eluviated Gleysol–Josephine series			Site 3. Fort Vermilion, Alberta. Humic Gleysol–Savage series		
Depth (cm)	*p*H	Exchangeable Al (ppm)	Soluble Mn (ppm)	*p*H	Exchangeable Al (ppm)	Soluble Mn (ppm)	*p*H	Exchangeable Al (ppm)	Soluble Mn (ppm)
				Nonlimed treatments					
0–15	5.1	42	32	4.5	385	7	4.1	164	48
15–30	4.9	220	8	4.2	714	2	3.9	263	48
30–45†	4.8	370	4	4.1	672	2	3.7	621	49
45–60†	4.7	516	2	4.0	616	2	3.7	931	49
60–90†	4.7	502	1	4.0	497	2	3.5	1058	45
90–120†	4.8	348	1	3.8	421	2	3.5	645	61
				Limed treatments					
0–15	6.1	1	8	6.0	5	1	5.6	1	7
15–30	5.0	139	11	4.4	535	2	3.8	414	43

†Values for these depths are for the combined samples from the limed and nonlimed treatments because *p*H at these depths was not affected by liming.

Table 2. Total yield of dry matter (kg/ha) in a 2-yr period from forage species on limed and nonlimed soil at three sites

Species	Site 1 (Dawson Creek) Nonlimed (*p*H 5.1†)	Site 1 Limed (*p*H 6.1)	Site 1 % Yield without lime‡	Site 2 (Spirit River) Nonlimed (*p*H 4.5)	Site 2 Limed (*p*H 6.0)	Site 2 % Yield without lime	Site 3 (Fort Vermilion) Nonlimed (*p*H 4.1)	Site 3 Limed (*p*H 5.6)	Site 3 % Yield without lime
				Grasses					
Timothy	5593 *a*§	5269 *b*	106	4175 *a*	6617 *a*	63*	3992 *ab*	5840 *a*	68*
Red fescue	3885 *b*	4996 *b*	78	2616 *b*	3953 *b*	66	3491 *b*	4477 *b*	78
Bromegrass	4619 *ab*	6517 *a*	71 **	2150 *b*	4876 *b*	44**	4964 *a*	6433 *a*	77*
Kentucky bluegrass	2643 *c*	3489 *c*	76*	2155 *b*	4136 *b*	52**	–	–	–
Russian wild ryegrass	–	–	–	–	–	–	0 *c*	1847 *c*	0**
				Legumes					
Alsike clover	2787 *b*	3529 *b*	79	962 *b*	4356 *b*	22**	590 *a*	4482 *a*	13**
Red clover	4115 *a*	5802 *a*	71*	2255 *a*	5386 *a*	42*	231 *ab*	4478 *a*	5**
Alfalfa	1627 *c*	3755 *b*	43*	21 *c*	4446 *b*	0.5**	143 *b*	4126 *ab*	4**
Birdsfoot trefoil	4046 *a*	4069 *b*	99	928 *b*	4502 *b*	21**	129 *b*	3464 *b*	4**

*,**Significant yield increases due to liming are shown at 5% (*) and 1% (**) levels for each species.
†*p*H values are for the 0–15-cm depth.
‡% Yield without lime $= 100 \times \frac{\text{yield without lime}}{\text{yield with lime}}$.
§Means in any one column (grasses or legumes) not followed by the same letter differ significantly ($P = 0.05$)

Table 3. Total yield of seed (kg/ha) in 2-yr period from forage species on limed and nonlimed soil at two sites

Species	Site 1 (Dawson Creek) Nonlimed (pH 5.1†)	Site 1 Limed (pH 6.1)	Site 1 % Yield without lime‡	Site 2 (Spirit River) Nonlimed (pH 4.5)	Site 2 Limed (pH 6.0)	Site 2 % Yield without lime
Grasses						
Timothy	326 *c*§	276 *c*	118	465 *a*	809 *a*	58**
Red fescue	1290 *a*	1188 *a*	109	488 *a*	446 *b*	109
Bromegrass	677 *b*	901 *b*	75	121 *b*	421 *b*	29*
Kentucky bluegrass	289 *c*	267 *c*	79	155 *b*	228 *c*	68 *
Legumes						
Alsike clover	518 *b*	763 *b*	68*	139 *b*	695 *a*	20**
Red clover	824 *a*	1050 *a*	78	340 *a*	715 *a*	48*
Alfalfa	–	–	–	0 *b*	260 *c*	0**
Birdsfoot trefoil	304 *c*	348 *c*	87	86 *b*	435 *b*	20**

*,**Significant yield increases due to liming are shown at 5% (*) and 1% (**) levels for each species.
†pH values for the 0–15-cm depth.
‡% Yield without lime $= 100 \times \frac{\text{yield without lime}}{\text{yield with lime}}$.
§Means in any one column (grasses or legumes) not followed by the same letter differ significantly ($P = 0.05$).

at site 2, 385 and 7 ppm, and at site 3, 164 and 48 ppm. The three experimental sites thus presented a wide range in soil acidity characteristics under which the response of different grasses and legumes were tested.

Forage and Seed Yields

At site 1, the least acidic of the three sites, dry matter yields of timothy, red fescue, alsike clover, and birdsfoot trefoil were not influenced by liming (Table 2), whereas bromegrass, Kentucky bluegrass, red clover, and alfalfa all gave yield increases when limed. Forage yields from nonlimed soil showed timothy and bromegrass as the best-suited grasses for this acid soil, and red clover and birdsfoot trefoil were the best legumes.

At site 2, where the soil was more acid than site 1 and had a very high content of exchangeable Al but a low content of Mn, the only species not influenced by liming was red fescue. Among the nonlimed treatments, timothy was the highest yielding grass and red clover the highest-yielding legume. Alsike clover and birdsfoot trefoil were very sensitive to acidity at this site, and alfalfa made essentially no growth without lime.

At site 3, where the soil was high in exchangeable Al, and very high in soluble Mn, red fescue was again the only species not influenced by lime but it was equal to timothy and outyielded by bromegrass in the nonlimed treatment on grasses. Russian wild ryegrass, seeded only at site 3, grew only when limed. The legumes produced scarcely any growth without lime, and all responded markedly to liming.

Seed yields of some species were also affected by soil acidity. At site 1, alsike was the only species that responded to liming (Table 3). At site 2, all species except red fescue produced more seed when limed, a response identical to that measured in herbage production. At both sites, red fescue and red clover were the top seed yielders for their respective groups grown without lime. At site 2, timothy also yielded well.

DISCUSSION

It is well known that crop species vary greatly in their tolerance to soil acidity, and that grasses are generally more tolerant than legumes. Among grasses, the fescues are especially tolerant, and among legumes, alsike clover is considered much more tolerant than red clover; and alfalfa is even less tolerant than red clover (Jackson 1967; Whittaker et al. 1964) Crop species have thus been ranked as to the minimum soil *p*H they can tolerate but in our experiments species varied considerably from site to site. Such a behavior is to be expected because different species vary in their sensitivity to Al toxicity (Foy and Brown 1964) as well as their sensitivity to Mn toxicity (Jackson 1967).

Results from the present work provide some specific new findings. Russian wild ryegrass is extremely sensitive to soil acidity. Contrary to earlier reports (Jackson 1967; Whittaker et al. 1964), red clover may be more tolerant than alsike clover grown for hay on some acid soils; this was found for our soils that were low in Mn but high in Al. As a seed crop, red clover produced superior yields and demonstrated a high tolerance to both Al and Mn. Similarly, the literature shows red fescue as more tolerant of acid soil than timothy (Jackson 1958). Our studies concur but only under conditions of high exchangeable Al. Both species showed some Mn tolerance and red fescue was unique by not responding to liming at any location, whether grown for herbage or seed.

Acid soils vary greatly in content of plant-available Al and Mn (Hoyt and Nyborg 1971*a, b*) as did the three soils in our experiments. Consequently, to precisely determine which species will be best suited to various acid soils, it would first be necessary to determine the tolerance of each species to Al and Mn, and then to determine the content of plant-aavilable Al and Mn in particular soils. Our results suggest that such an approach may be useful. For example, solution culture experiments have demonstrated that red clover is sensitive to Mn toxicity, whereas alsike clover is resistant to excess Mn (Jackson 1967). Our data showed how field-grown red clover harvested for hay was more tolerant than alsike clover in the one soil low in Mn, but slightly less tolerant in the two soils high in Mn.

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