Response of Forage Crops to Dolomitic Lime

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Introduction

Most pastures of the Tras-os-Montes region in Northern Portugal, are established on acid soils. These soils normally have very low levels of exchangeable Ca and Mg which impede the normal development of plants and can also cause animal health problems. Grass tetany, a metabolic disorder in ruminants related to a low level of Mg in forages, has been frequently observed in this region, especially in late winter or early spring.

The objective of this study is to verify whether correcting the acidity of a representative soil from this region with dolomitic lime improves the quality and yield of ryegrass, tall fescue, white clover and subterranean clover. The concentration of Mg in the forage will be of special interest. A value greater than 0.20% (10) is commonly accepted as the level where the occurrence of grass tetany is diminished. However if the forages have a high K concentration, greater than 3%, it is suggested that the Mg level should be higher than 0.20% (5).

Materials and Methods

The experiment was conducted in polyethylene pots containing 4 kg of air dry soil (< 5 mm fraction) taken from a sandy loam xerofluvent whose characteristics are found in Table 1. The forage species tested were *Trifolium subterraneum* L., cultivar

Table 1. Chemical properties of the soil(1).

pH (H_2O)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	H^{+} + Al^{+++}	CEC	Base saturation	Organic matter	P_2O_5	K_2O
	meq/100 g						%		ppm	
5.3	1.32	0.20	0.04	0.25	8.16	9.83	16.99	1.53	>200	140

(1) top 20 cm; pH in 1:2.5 soil solution ratio; Exch. bases by 1 *N* ammonium acetate pH 7.0; Exch. H^{+} and Al^{+++} by barium chloride-triethanolamine, pH 8.0; organic matter by method of Tinsley (C x 1.724); P_2O_5 and K_2O by method of Enger-Riehm.

Clare (subterranean clover), *Trifolium repens* L., cultivar G. Huia (white clover), *Festuca arundinacea*, cultivar Manade (tall fescue) and *Lolium perenne* x *L. multiflorum*, cultivar G. Manawa (hybrid ryegrass). The forages were sown in November and each species was thinned to 25 plants per pot. The legume seeds were inoculated with Rhizobia.

Each species were subjected to soil treatments of three levels of dolomitic lime (63.5% $CaCO_3$ and 37.8% $MgCO_3$): 0, 15 or 30 g/pot which corresponds to 0, 7500 and 15000 kg/ha, respectively. All treatments were replicated four times. A nutrient solution was applied before the species were sown. The quantities, added in mg/pot were: N 840 for grasses and 112 for legumes, P 414, K 520, S 100, B 2.7, Mo 0.1, Zn 13.2, Cu 3.2, Mn 11.0, Fe 20.0 (7).

The plants were irrigated daily with distilled water up to two-thirds of their maximum water retention capacity.

The tall fescue, ryegrass and subterranean clover herbage were cut at 3 cm above the soil in March, April and May. The white clover herbage was cut in April, May and June. All species were flowering at the time of their last cutting.

The herbage was dried at 60°C for 24 hours for the determination of dry matter production, and ground to pass a 1-mm screen. The ground tissue was digested using nitric-perchloric acid and Ca and Mg determined by atomic absorption spectrophotometry and K by flame photometer. After the final harvest, the soil was analyzed for pH to determine if a shift in pH occurred.

Results and Discussion

Dolomitic lime significantly increased ($P < 0.05$) the total D.M. production of all the species (Table 2). A positive yield response occurred for all white clover cuttings,

TABLE 2. Effect of species and rate of dolomitic lime on forage dry matter production(1).

Species and rate of dolomitic lime(2)	Cutting 1	Cutting 2	Cutting 3	Total
	g/pot			
Tall fescue				
0 g/pot	5.40	9.91	15.65	30.96
15	4.80	11.50	20.83	37.13
30	5.12	12.20	18.61	35.93
LSD (0.05)	n.s.	1.78	4.87	5.52
Ryegrass				
0 g/plot	9.38	12.58	23.55	45.51
15	9.34	13.77	27.65	50.76
30	10.29	14.13	30.56	54.98
LSD (0.05)	n.s.	1.37	3.45	4.15
Sub. clover				
0 g/plot	5.42	9.12	8.15	22.69
15	6.45	12.81	14.00	33.26
30	6.43	12.84	14.97	34.24
LSD (0.05)	n.s.	3.56	3.35	4.14
White clover				
0 g/pot	4.58	3.28	3.96	11.82
15	8.35	14.44	13.26	36.05
30	8.63	14.86	16.54	40.02
LSD (0.05)	1.28	3.41	3.40	6.80

(1) Values are means of 4 replications
(2) g/pot

with an increase in D.M. production from the first level of lime of 82%, 340% and 234% for the first, second and third cuttings, respectively. The other species had significant yield responses only for the second and third cuttings. Fescue increased 15 and 33%, ryegrass 9 and 17% and subterranean clover 41 and 77%, respectively.

While all species responded well to the liming treatments the total yield of all cuttings of tall fescue, white clover and subterranean clover did not yield significantly higher ($P < 0.05$) at the 30 g than at the 15 g treatment. However ryegrass production did respond to the application of 30 g/pot ($P < 0.05$). The increase obtained at the first level of liming was 20%, 47%, 205% and 12%, respectively for the four species. The ryegrass had a 20% increase at the second level of liming. The average final pH obtained with 0, 15 and 30 g of dolomitic lime per pot was 4.9, 6.0 and 6.6, respectively (Table 3).

TABLE 3. Effect of species and rate of dolomitic lime on final soil pH values[1]

Treatments	Fescue	Ryegrass	Sub. clover	White clover
g/plot		soil pH		
0	4.7	4.8	4.7	5.2
15	6.2	6.3	5.8	6.0
30	6.7	6.6	6.6	6.7

(1) Values are means of 4 replications

The increase in D.M. production with dolomitic lime is probably due to an improvement of the general conditions of nutrition of which the most commonly suggested are an improved assimilation of P and a decrease in the solubility of Al and Mn (11, 16, 17). Although no data was recorded, the treatments in which the acidity was corrected had longer roots with much more branching and root hair development and the number of nodules on the clovers were much greater. It has been verified that nodulation is affected not only by the acidity of the medium but also by the lack of Ca (1).

While Ca concentration did increase with dolomitic lime application, the increase was not significant ($P < 0.05$) for the two grasses tested, with the exception of the second cutting of tall fescue (Table 4). For all treatments, the Ca concentrations that ranged from 0.40 to 0.67% in the grasses and from 0.76 to 1.89% in the clovers are generally considered as sufficient for a good plant growth (1, 13).

The Mg concentration was significantly improved ($P < 0.05$) from that obtained in the control (Table 4) when dolomitic lime was applied, although the analytical values were generally higher in the 30 than in the 15 g/pot treatment the differences were not significant at the $P < 0.05$. The average Mg concentration of tall fescue and ryegrass increased from 0.11 and 0.10% in the control to 0.33 and 0.24%, respectively in the 15 g lime treatment. In the white clover and subterranean clover, it increased from 0.18% in both controls to 0.42 and 0.51%, respectively in the 15 g treatment. In all cuttings, the Mg levels obtained with the dolomitic lime treatments were greater than 0.20, the value commonly accepted as sufficient for ruminant nutrition.

The levels of Mg found in the two grasses on the unlimed soil were very low (0.09 to 0.12%), but no Mg deficiency symptoms were observed. The symptoms usually occur, according to Grunes *et al.* (5) when the percentage of Mg in the D.M. varies between 0.05 and 0.10. Embleton (3), however, referred to somewhat higher Mg values. The Mg level for the clovers were much higher than those of grasses on the unlimed soil and only in the first cutting of the white clover and third cutting of the subterranean clover did the Mg concentration, 0.14 and 0.11% respectively, approximate the plant deficiency value of 0.12-0.14% (13).

The occurrence of low tissue Mg is reasonable since the level of exchangeable Mg in the soil, 0.20 meq/100 g, is considered low (2). Hogg and Karlovsky (8) stated that when the exchangeable Mg is less than 0.20 meq/100 g of soil, a deficiency should be expected. Felbeck (4) suggested that application of Mg should be recommended when the level of exchangeable Mg is less than 0.41 meq/100 g of soil. Horvath and Todd (9) recommended that for good plant growth the exchangeable Mg level ought

TABLE 4. Effect of species and rate of dolomitic lime on the concentration of Ca, Mg and K in herbage dry matter(1)

Species and rate of dolomitic lime(3)	Calcium			Magnesium			Potassium		
	Cutting 1	Cutting 2	Cutting 3(2)	Cutting 1	Cutting 2	Cutting 3(2)	Cutting 1	Cutting 2	Cutting 3(2)
	%								
Fescue									
0	0.40	0.43	0.40	0.12	0.10	0.10	3.76	2.09	1.29
15	0.41	0.61	0.43	0.29	0.36	0.35	3.51	2.19	1.16
30	0.47	0.54	0.43	0.32	0.35	0.36	3.78	2.21	1.35
LSD (0.05)	n.s.	0.08	n.s.	0.06	0.02	0.02	n.s.	n.s.	n.s.
Ryegrass									
0	0.43	0.67	0.42	0.09	0.11	0.09	3.69	1.86	1.14
15	0.44	0.67	0.47	0.21	0.27	0.24	3.93	2.04	1.23
30	0.46	0.67	0.44	0.23	0.30	0.25	3.67	2.28	1.34
LSD (0.05)	n.s.	n.s.	n.s.	0.02	0.03	0.04	n.s.	n.s.	0.17
Sub. clover									
0	1.12	0.78	0.76	0.24	0.18	0.11	3.00	2.64	2.34
15	1.26	1.39	1.59	0.49	0.48	0.55	2.42	2.05	1.26
30	1.48	1.38	1.89	0.52	0.48	0.61	2.44	2.30	1.36
LSD (0.05)	0.13	0.15	0.32	0.05	0.05	0.07	0.41	n.s.	0.59
White clover									
0	1.12	1.25	1.20	0.14	0.21	0.20	3.39	3.57	3.42
15	1.34	1.37	1.34	0.35	0.40	0.51	3.20	2.10	1.45
30	1.50	1.54	1.60	0.36	0.42	0.56	3.36	1.19	1.54
LSD (0.05)	0.28	n.s.	0.24	0.05	0.06	0.08	n.s.	0.54	0.95

(1) Values are means of 4 replications
(2) All species exhibit flowers
(3) g/pot

to be at least twice the exchangeable K^+ level and the Ca:Mg ration ought to be 5:1. In this soil, the Mg level was less than the K level and the Ca:Mg ratio was 6.6:1.

Conforming to what would be expected (13, 14, 18, 19), the Ca and Mg concentrations of the clovers were superior to those of grasses. However, the difference in levels of Mg between the grasses and clovers is not as accentuated as in the case of Ca, a fact already observed by Metson and Saunders (14). The fact that the legumes have greater concentrations of Ca and Mg than the grasses points out that the risk of grass tetany would be less in legume or grass-legume pastures.

The K concentration in the herbage was also determined (Table 4) because K utilization could be less because of the dolomitic lime application. The K concentration of the treatments in which the acidity had been corrected was not significantly different ($P < 0.05$) than those found in the control, with exception of the second and third cuttings of white clover which decreased 41% and 58% respectively, the third cutting of subterranean clover which decreased 48% and the third cutting of ryegrass which increased 8% when the percentage change is calculated from comparison of the control with the 15 g liming treatment. The K concentration decreased in general from the first to the final cutting. In the final cutting, the K level in the grasses was very low, ranging from 1.14 to 1.35%, but no deficiency symptoms were observed. These symptoms usually occur when the percentage of K is less than 2.2% (15, 22). The K concentration in the clovers is considered medium (12, 21).

The great decrease in the K levels in the 2nd and 3rd cuttings is due perhaps to the fact that the K, in contrast to Ca and Mg, is a nutrient with major seasonal variation, having marked monthly fluctuations which are in general similar in grasses and legumes (14). Generally the levels of K in forages attains a maximum level at the end of winter, decreasing after this until the beginning of summer at which time it attains its lowest value (6, 14).

Conclusions

The results obtained showed that the correction of acidity by the use of dolomitic lime (63.5% $CaCO_3$ and 37.8% $MgCO_3$), produced a quantitative and qualitative improvement in production. The benefit of this action is due to the general improvement of the nutritional status of the soil, shown by the pH (H_2O) rise to average values of 6.0 (15 g/pot) and 6.6 (30 g/pot), and to an increase in the available Ca and Mg for the plants.

The total D.M. production of tall fescue, subterranean clover and white clover increased 20, 47 and 205%, respectively, with the addition of 15 g/pot of dolomitic lime. Ryegrass, unlike the other forages, gave additional increase in production with 30 g of dolomitic lime per pot ($P < 0.05$).

The qualitative improvement of production refers essentially to the increased Mg concentration in the D.M. to values greater than 0.20%, a value which is considered sufficient for good plant development as well as for supplying animal needs. The average Mg concentration of tall fescue, ryegrass, subterranean clover and white clover increased to 0.33, 0.24, 0.51 and 0.42% with the application of 15 g/pot of dolomitic lime ($P < 0.05$).

Pastures established on the acid soils of the Tras-os-Montes region with low levels of exchangeable Ca and Mg should have the soil pH corrected with dolomitic lime and not with calcitic lime. Legumes contain considerably higher concentrations of Ca and Mg than grasses and should always be grown in pastures whenever possible in order to reduce the risk of incidence of grass tetany.

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