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Evaluation of soil amendments in perennial ryegrass pastures associated with white and red clover in small-scale milk production systems

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ABSTRACT

Objective: Evaluate the effect of agricultural lime and dolomite in a perennial ryegrass cv. Tetragrain pasture associated with white clover cv. Ladino and red clover cv. Kenland.

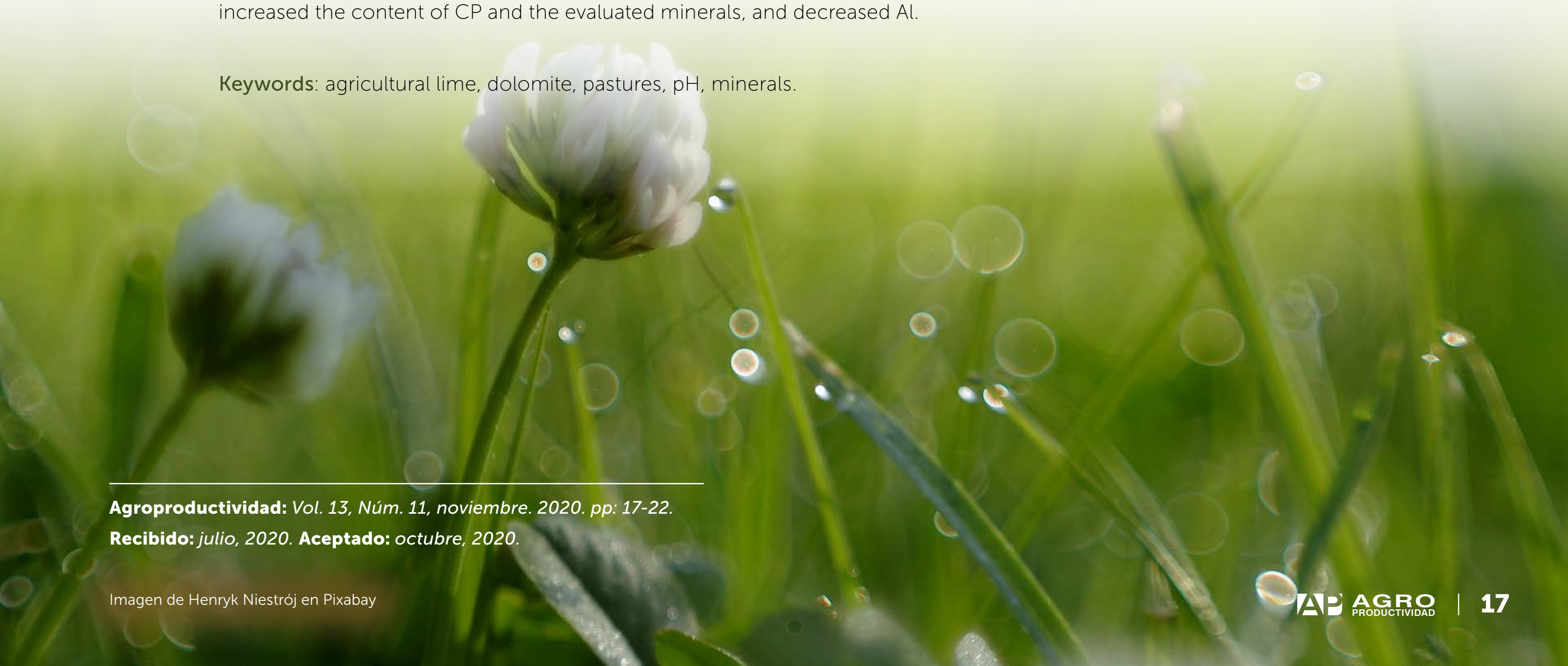
Methodology: Three soil amendment treatments were established in a perennial ryegrass pasture with white and red clover using a split-plot experiment design. The treatments were: T1=control (without soil amendment), T2=agricultural lime, and T3=dolomite. The evaluated variables were pasture height, herbaceous mass (HM), dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein (CP), *in vitro* digestibility of dry matter (IVDDM), and metabolizable energy (ME).

Results: Significant differences ($P \leq 0.05$) were observed for experimental periods in pasture height, DM, CP, ADF, OM, IVDDM, and ME. For treatments, there were significant differences ($P \leq 0.05$) in pasture height, DM, CP, and OM. The interaction between experimental periods (P) and treatments (T) was not significant for any variable ($P > 0.05$). Regarding the soil chemical composition results, we observed a decrease in pH at the end of the experiment; however, there was an increase in Ca, Mg, and total N, and a decrease in Al.

Limitations/implications: Given the low impact of the treatments in most of the evaluated variables, it is necessary to expand the study to different doses, type of soil amendments, and handling conditions to control the impact of the producers' practices in pastures.

Conclusions: The use of soil amendments did not increase pH, DM production, NDF and ADF content, IVDDM, or ME, but increased the content of CP and the evaluated minerals, and decreased Al.

Keywords: agricultural lime, dolomite, pastures, pH, minerals.



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INTRODUCTION

Grass-legume mixed pastures usually have improved forage yields due to the different use of resources, complementation of niches, and mutualistic interaction (Ergon *et al*., 2016).

Among the factors that affect soil, pH influences soil microorganisms, plant composition, and its nutrients (Fernández-Calviño & Bååth, 2010). If the pH is lower than 5 it is important to implement practices to increase its value (Ryant *et al*., 2016). Soil acidification frequently occurs in warm and humid climates, with high precipitation levels (Dambrine, 2018).

Besides pH, soil mineral content largely determines plant species and their characteristics. Ca is important for plant structure, as it strengthens the cellular membrane and wall, forming up to 90% of its composition. Mg is essential during photosynthesis, cell division, and protein synthesis (Maathuis & Podar, 2011). Nitrogen is related to increased forage production, as it participates in tissue formation (Flores-Aguirre *et al*., 2018). P is necessary during photosynthesis and root development (Sierra-Alarcón *et al*., 2019). Moreover, K is important for phloem loading, assimilation transport, nitrogen metabolism, and storage processes (Kayser & Isselstein, 2005).

Management of acid soils includes the addition of pH soil amendments (FAO, 2019), such as agricultural lime, which contains calcium carbonate, and dolomite, which besides containing calcium carbonate, provides Mg (Arévalo & Castellano, 2009), both used to increase soil pH, Ca, and Mg (Bambara & Ndakidemi, 2010). When applied in the superficial layers (up to 10 cm), these soil amendments can decrease soil acidity (Corrêa *et al*., 2009).

In subtropical climate pastures, and grasslands in general, soil amendments are rarely used to increase pH and mineral content; furthermore, few studies have evaluated how these soil components affect the physicochemical and agricultural characteristics of pastures. Therefore, this study aimed to evaluate the effect of agricultural lime and dolomite in a perennial ryegrass (*Lolium perenne*) cv. Tetragrain pasture associated with white clover (*Trifolium repens*) cv. Ladino and red clover (*Trifolium pratense*) cv. Kenland.

MATERIALS AND METHODS

Area of study

The study was performed in the Aculco municipality, located at the northwest of Estado de México, at an altitude of 2440 masl, 20° 06′ and 20° 17′ N and 99° 40′ and 100° 00′ W, with a humid subtropical climate (Celis-Álvarez *et al*., 2016), a mean temperature of 16.5 °C during the experiment, and 729.8 mm of precipitation during the experiment. The experiment lasted 336 days, from March 27, 2019, to February 4, 2020.

Pasture establishment

A 1.35 ha pasture was established in August 2018 with 30 kg/ha of perennial ryegrass cv. Tetragrain seeds, 3 kg/ha of white clover cv. Ladino seeds, and 6 kg/ha of red clover cv. Kenland seeds. The pasture was fertilized with 60N-80P_2O_5-60K kg ha^{-1}. Subsequently, it was fertilized every four weeks with 50 kg ha^{-1} of urea. The pasture was under a cut and carry system. Irrigated once a month, from March to June. The pasture was divided into three experimental plots of 0.45 ha. Soil samples were collected at the beginning and at the end of the experiment to determine pH, cation exchange capacity (CEC), Ca, Mg, N, P, K, and Al.

Treatments

Three treatments were established, one in each experimental plot. The first was a control treatment (T1), in which no soil amendments were added; the second and third treatments consisted of applying 400 kg of agricultural lime (T2) and dolomite (T3), respectively.

Agronomic variables

The experiment lasted 336 days, divided into 12 experimental periods of 28 days each. Sampling was performed on day 28, where we also measured the compressed height of the pasture using a rising plate meter, taking 15 measurements per treatment following a "W" pattern (Celis-Álvarez *et al*., 2016). HM (kg DM ha^{-1}) was determined using three randomly distributed 0.5 m^2 (2 m × 0.25 m) quadrants per treatment. Samples were collected by cutting with scissors the forage within the quadrant at ground level. These samples were subsequently processed to determine the chemical composition of the forage in each treatment.

Forage chemical composition

Forage samples were analyzed following standard procedures (Celis-Álvarez *et al*., 2016). The IVDDM was determined using the Ankom-Daisy method. The ME was calculated with the CSIRO (2007) formula:

$$ME = 0.172\ IVDDM\ (\%) - 1.707.$$

Statistical analysis

We used a split-plot experimental design, in which treatments with soil amendments (T1, T2, or T3) are considered fixed effects, and the 12 experimental periods are the random effects. The Minitab V14 statistical software was used to compare results using the Tukey test at a significance level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Soil chemical composition

Table 1 shows the initial and final experimental soil values. The average values of pH, Ca, P, K, and Al decreased in T2 and T3, compared to T1 (control group). N remained the same in T1 and T2; however, the values in T3 were lower.

Pasture variables

The production of HM (Table 2) did not increase linearly with the experimental periods; thus, the treatments with soil amendments did not affect the production of HM. There were significant differences ($P \leq 0.05$) for pasture height between T and P.

Forage chemical composition

There were significant differences ($P \leq 0.05$) between T for DM, CP, and OM (Table 2). Significant differences ($P \leq 0.05$) were found between P for DM, CP, ADF, OM, IVDDM, and ME. The interaction between T and P was not significant for any variable.

Soil chemical composition, height, and plant mass

One of the factors that affect soil is pH, as the changes it induces occur close to the roots, creating a favorable environment for pasture growth (Higgins *et al*., 2012; Minasny *et al*., 2016).

Norton *et al*. (2018) mention that the highest increase in pH occurs in the superficial layer of the soil, from 0 to 2.5 cm in depth. However, in this study, we observed a decrease in pH, which could be explained by the increase of N in the soil, as this element is an important contributor to soil acidification, mainly in T1 and T2, where N concentration increased practically 5.2 times compared to the beginning of the experiment (Table 1).

The most important minerals for soil structure are Ca and Mg; the balance between these two ions is between 5 and 7 (Higgins *et al*., 2012).

With the reduction of pH, Al increases its solubility and, as a result, the ion exchange decreases, causing nutrient deficiencies, mainly of Ca, Mg, and P (Horst *et al*. 2010). At the beginning of the experiment, we observed high levels of Al; at the end, Al levels decreased. These results indicate that both lime and dolomite decrease Al levels in soil, which somehow benefits plant development.

As forage age increases, the concentration of elements with greater solubility decreases, dominating those with less digestibility. DM also depends on cutting age and water availability, since ryegrass requires 48 to 100 mm of water per month (Sierra-Alarcón *et al*., 2019).

The average HM for T1 was 766 kg DM ha^{-1}, with 305.1 g kg^{-1} of DM; this differs from that reported by Muñoz *et al*. (2016), who evaluated perennial ryegrass with heights ranging from 5 to 11 cm, similar to the ones in this study. Moreover, Tiecher *et al*. (2013), 11 months after applying a high dose of lime (3.2 t ha^{-1}), reported a one-point increase in soil pH, which had an initial value of 4.5. They also reported an increase in Ca and Mg, and a decrease in Al.

Table 1. Chemical characteristics of the pasture soil at the beginning and end of the experiment.

Variable	At the beginning of experiment	At the end of experiment			Mean
		Treatments			
		T1	T2	T3	
pH	5.3	5.2	5.1	4.7	5.1
soluble Ca (mg kg^{-1})	28.3	950.3	900.8	823.1	675.6
Mg (mg kg^{-1})	41.3	75.2	173.3	133.2	105.8
Total N (mg kg^{-1})	500.0	2600.0	2600.0	1100.0	1700.0
P (mg kg^{-1})	21.9	191.0	185.5	174.5	143.2
K (ppm)	23.4	43.5	30.1	20.1	29.3
Al (cmol kg^{-1})	38.6	7.0	10.4	1.6	14.4
CIC (cmol kg^{-1})	40.6	25.50	30.9	33.40	40.6

T1, control; T2, agricultural lime; T3, dolomite; CEC, cation exchange capacity; ppm, parts per million; cmol, centimoles.

Table 2. Pasture height (cm), herbaceous mass (HM), chemical composition (g/kg DM), *in vitro* digestibility of dry matter (g kg^{-1} DM), and metabolizable energy (MJ kg^{-1} DM) per treatment and experimental period (28 days).

Treatment	Variable								
	Sward height	HM	DM	CP	NDF	ADF	OM	IVDMD	eEM
T1	6.6^{b}	1766.0	305.1^{a}	129.5^{b}	499.8	281.8	887.0^{c}	763.8	11.4
T2	6.4^{c}	1831.0	300.3^{b}	136.5^{a}	501.6	284.1	889.0^{b}	758.1	11.3
T3	6.7^{a}	1873.0	297.7^{c}	140.6^{a}	498.4	285.0	891.0^{a}	774.5	11.6
SEM_T	0.2	53.7	3.7	5.1	23.6	3.5	2.2	8.3	0.1
Experimental periods									
1	6.0^{g}	1540.0	233.1^{k}	131.1^{e}	446.5	226.0^{e}	872.0^{j}	765.7^{c}	11.5^{c}
2	8.8^{b}	1853.0	317.8^{d}	130.1^{e}	464.6	225.2^{e}	882.0^{i}	729.5^{c}	10.8^{c}
3	6.5^{f}	1959.0	285.4^{f}	126.3^{e}	439.2	220.0^{e}	885.0^{g}	757.5^{c}	11.3^{c}
4	8.4^{c}	2084.0	488.0^{a}	91.4^{f}	478.8	234.9^{e}	900.0^{a}	726.1^{c}	10.8^{c}
5	6.2^{f}	1425.0	252.2^{j}	122.5^{e}	477.5	359.6^{c}	894.0^{c}	803.7^{b}	12.1^{b}
6	6.0^{g}	1514.0	348.2^{b}	129.5^{e}	585.6	437.2^{a}	897.0^{b}	679.1^{d}	10.0^{d}
7	5.8^{h}	1602.0	287.7^{e}	144.1^{d}	517.5	394.0^{b}	894.0^{c}	745.2^{c}	11.1^{c}
8	6.4^{e}	1932.0	232.3^{l}	150.1^{c}	464.5	352.4^{c}	892.0^{d}	771.5^{c}	11.6^{c}
9	10.6^{a}	1927.0	279.3^{g}	144.7^{d}	529.7	240.3^{e}	892.0^{d}	800.8^{b}	12.1^{b}
10	8.8^{b}	2587.0	338.5^{c}	124.1^{e}	569.1	273.1^{d}	887.0^{f}	740.2^{c}	11.0^{c}
11	5.0^{i}	1478.0	277.9^{h}	162.5^{b}	523.0	224.5^{e}	890.0^{e}	837.6^{a}	12.7^{a}
12	4.2^{j}	1977.0	272.4^{i}	170.0^{a}	502.8	216.5^{e}	883.0^{h}	829.1^{a}	12.6^{a}
SEM_P	1.8	333.0	69.3	20.8	42.6	82.5	7.7	46.1	0.4
SEM_{int}	0.1	74.3	5.0	2.1	7.8	3.0	1.0	5.6	0.2

T1, control treatment; T2, lime; T3, dolomite; HM, herbaceuos mass; DM, Dry matter; CP crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; OM, organic matter; IVDMD, *in vitro* dry matter digestibility; SEMT, standard error of the mean for treatments; SEMP, standard error of the mean for experimental periods; SEMint, standard error of the mean for interaction T*P. $^{a, b, c, d, e, f, g, h, i, j, k, l}$ $P \leq 0.05$.

The evaluated soils (Table 1) had optimal P and CEC levels; however, Ca, Mg, N, and K levels were below the adequate levels before establishing the treatments. After the experimental periods, pH, CEC, and Al levels decreased; in T3, K levels also decreased. The soil components that increased in all treatments were Ca, Mg, N, and P; K levels only increased in T1 and T2 (NOM-021-SEMARNAT-2000). The values reported after applying the soil amendments could be explained by their uncertain effects, as well as in soils with high P levels that can be shown at the end of the experiment, there may be an absence of response to the increase in pH (Poozesh *et al*., 2010). The considerable increase of N in the soil could be related to the decrease of Al, which decreases root development (Kumar y Kumar, 2015); therefore, low Al allows correct root development, increasing legume N fixation; thus, it can also increase the availability of P through the release of fusidic acid that mobilizes and increases the availability of P (Bambara & Ndakidemi, 2010).

Forage chemical composition

The content of CP depends on the maturity of forage (Alfonso Ávila *et al*., 2012); CP decreases due to the loss of protein in vegetative structures and the increase of protein in seeds (Haj-Ayed *et al*., 2000). For T1, the average CP was 129.5 g kg^{-1} DM (Table 2), below that reported for the rainy season by Plata-Reyes *et al*. (2018) and Sierra-Alarcón *et al*. (2019).

The NDF and ADF content for T1 was 499.8 and 281.8 g kg^{-1} DM, respectively (Table 2). These results were similar for the rest of the treatments and that reported by Garduño-Castro *et al*. (2009). This arises from the fact that the nutritional value of forage association decreases with time, which reflects in forage digestibility, which on average for T1 was 763.8 g kg^{-1} DM (Table 2), higher than that reported by Plata-Reyes *et al*. (2018). For T1, the ME was 11.4 MJ kg^{-1} DM, higher than that reported by Plata-Reyes *et al*. (2018) for perennial ryegrass.

CONCLUSIONS

The use of soil amendments in pastures did not increase pH, DM production, NDF and ADF content, IVDDM, or ME, but it increased the content of CP and the evaluated minerals, and decreased aluminum, which is a limiting factor for forage growth in acid soils.

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