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Liquid lime and conventional agricultural lime in soil acidity correction and characteristics of *Brachiaria brizantha* cv. Braúna

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Abstract. The effect of applying liquid limestone and conventional limestone together with regrowth in correcting soil acidity and characteristics of *Brachiaria brizantha* cv. Braúna was evaluated. The treatments were randomly distributed in a 3×3 factorial scheme, with three soil corrections: 1) control; 2) conventional limestone; 3) liquid limestone and three regrowths with a cutting interval of 21 days at 10 cm from the soil, with 4 replicates. The soil pH and base saturation were evaluated in each regrowth in the 0 to 20 cm layer, in addition to the production and bromatological characteristics of Braúna grass. Conventional limestone was efficient in increasing the pH, saturation and production of root dry matter. There was a regrowth effect, where there was an increase in the levels of dry matter, NDF, ADF, hemicellulose and cellulose, and a reduction in the levels of crude protein. The use of conventional limestone is recommended to correct acidity and increase base saturation, as there is greater root development. *Brachiaria brizantha* cv. Braúna is influenced by regrowth at successive cutting intervals of 21 days, with reduced productivity at each cut and reduced crude protein content.

Key words: *Brachiaria brizantha*, liming, productivity, regrowth vigor.

INTRODUCTION

Soil acidity is a factor that limits crop yields. Acidic soils contain two chemical elements: aluminum and manganese, which at high levels are toxic to plants, resulting in low nutrient utilization (Fonseca, 2015). Forage plants react differently to acidity; some adapt, presenting average production, while others need soils with a higher pH to establish themselves and present good production (Santana, 2010).

The loss of soil potential is caused by the low availability of nutrients and the high concentration of aluminum in solution (Nolla & Anghinoni, 2004). Aluminum at high levels leads to thickening of roots in addition to reduced growth. According to these authors, in soils with a pH below 5.5, aluminum begins to have a toxic effect on plants, especially on the roots, which begin to have less space due to the thickening of their roots, causing the plant to have a lower absorption of nutrients and water. These effects tend to increase as the soil pH decreases (Dutra et al., 2025).

Another factor that affects plant performance is regrowth vigor, which is the plant's ability to recover after intense cutting or grazing. For Barbero et al. (2015), the intensity and frequency with which cuts are made mainly influence the initial phase, since plant growth rates are related to the leaf area present after cutting and also the light intercepted by the leaves for photosynthesis.

In view of the above, it is known that acidity is toxic to most plant species, and as such, the liming technique with the use of soil correctives is the most recommended way of correcting it. According to Freire (2013), the use of correctives can reduce acidity, in addition to stimulating microbial activity, favoring N fixation and increasing the availability of nutrients for plants, thus neutralizing aluminum toxicity. The most commonly used material for correcting soil acidity is limestone, as it is made up of calcium and magnesium carbonates in varying amounts.

The calcium carbonate present in limestone is a salt with very low solubility, but the small dissolution that occurs in the presence of carbon dioxide is enough to trigger a series of reactions that result in the neutralization of acidity (Raij, 2011).

New technologies are currently being developed that aim to improve the root environment, so that crops develop more quickly, and can serve as a complement or substitute for the application of limestone by broadcasting, without incorporation. The application of a solution of calcium carbonate microparticles can provide the reaction of limestone with the soil more quickly, thus increasing the soil pH and the availability of phosphorus for plants, consequently resulting in greater crop productivity (Nascente & Cobucci, 2015).

In this sense, Bambolim et al. (2015), when evaluating the effect of applying liquid limestone and conventional limestone, found that liquid limestone was not effective in correcting soil acidity and was unable to reduce aluminum saturation and potential acidity, only increasing the concentration of Ca in the soil. However, the application of conventional limestone provided correction of soil acidity, thus confirming the effects of conventional limestone observed in the literature. It is worth noting that liquid limestone has not been fully proven to be effective, and its effects on the characteristics of forage are still little known, as there is little information available regarding its use in comparison with conventional limestone.

This study aimed to evaluate the effect of applying liquid limestone and conventional limestone together with regrowth in correcting soil acidity and characteristics of *Brachiaria brizantha* cv. Braúna.

MATERIALS AND METHODS

The research with *Brachiaria brizantha* cv. Braúna was carried out in a greenhouse located at the State University of Southwest Bahia, Juvino Oliveira Campus, Itapetinga, BA (15°38’46’’ south latitude, 40°15’24”, west longitude and an average altitude of 280 m), during the period from December 2018 to April 2019.

A completely randomized experimental design was used, in a 3×3 factorial scheme, with three soil corrections: control, conventional limestone and liquid limestone. And three regrowths at 21-day intervals, with four replications, totaling 36 experimental units.

A sandy clay soil was used (according to the soil analysis protocol) collected from the Valeu Boi farm, located in the municipality of Encruzilhada-Bahia. The soil was collected in the arable layer (0 to 20 cm), after being broken up and passed through a sieve with a four-millimeter mesh, the material was collected for soil analysis and then the pots, with a capacity of 14 L, were filled with 10 kg of dry soil. The soil presented the following chemical attributes in the 0–20 cm depth layer: pH_{H2O} of 4.8; 6 mg dm^{-3} of P; 25 g dm^{-3} of organic matter; exchangeable contents of H+Al, Al, Ca, mg and K of 6.4, 0.5, 1.7, 1.2 and 0.41 cmolc dm^{-3} respectively and base saturation of 34%. Its physical composition showed the following particle size characteristics: 495 g kg^{-1} of sand, 85 g kg^{-1} of silt, and 420 g kg^{-1} of clay.

Based on the results of the soil analysis, and in accordance with the recommendations of the Soil Fertility Commission of the State of Minas Gerais (Alvarez, 1999), in which *Brachiaria brizantha* is defined as having a high technological level, there was a need for liming and the application of phosphorus, with no need for the application of potassium. Phosphorus showed low availability, and an application of 110 kg of P_2O_5 ha^{-1} corresponding to 0.78 g pot^{-1} of simple superphosphate was carried out. Nitrogen fertilization was divided into 3 applications, the first being carried out after sowing and the following after each cut, totaling 150 kg N ha^{-1} corresponding to doses of 0.35 g pot^{-1} of urea per application.

The criterion adopted for recommending liming was base saturation, which was recommended to rise to 45% for *Brachiaria brizantha* cv. Braúna. Therefore, from the calculations performed, the quantity of 1.07 t ha^{-1} of conventional limestone was obtained, and for liquid limestone, the proportion of 10 L (according to the manufacturer's recommendations) for 1 ton of conventional limestone was used.

The liquid limestone used in the experiment had 16.5% Ca, 3.5% mg and a density of 1.67 g mL^{-1}, according to information provided by the manufacturer. The conventional limestone was dolomitic with 29.0% calcium oxide, 19% magnesium oxide and PRNT of 82.02%.

After filling the pots, liquid limestone and conventional limestone were applied to the surface; after applying the limestone, the pots were incubated for 30 days to neutralize the soil acidity by applying different types of limestone. During incubation, the soils were maintained at 80% of their field capacity, with replacement being carried out at one-day intervals. To determine field capacity, all pots with dry soil were weighed, soaked with water and, after the water had completely drained, weighed again. This weight was used to replace water lost through evapotranspiration.

Thirty days after incubation of the pots, *Brachiaria brizantha* cv Braúna was planted, using approximately 20 seeds per pot, at a depth of approximately 2 cm. Fertilization with simple superphosphate and urea was carried out 15 days after planting. After each regrowth, nitrogen fertilization was carried out in the remaining pots.

Thirty days after seed germination, thinning was carried out, leaving 4 plants per pot, where the criterion used was the vigor and homogeneity of the plants. Twenty days after thinning, a uniform cut was carried out at 10 cm above the soil and from the uniformity, the evaluations began.

Plant analysis

At the end of each cutting period, four pots per treatment were dismantled, so that in each 21-day interval, 12 pots were dismantled, obtaining dismantled at 21, 42 and 63 days counted from the standardization cut. The roots were cleaned with running water and their volume and dry mass were evaluated. Before each dismantling, the soil was collected in each pot in the 0 to 20 cm layer, collecting it at four points in the pots, where they were combined to obtain the composite sample.

To assess dry matter, the pots of each regrowth were dismantled with the aid of running water, removing the entire plants, which were later dissected into leaves, stems, roots and residue. The aerial part sample was considered above the recommended 10 cm cutting line, and the residue corresponded to production below the cutting line, where production data were presented in kg DM ha^{-1}, considering the pot area of 0.07065 m^2.

Immediately after cutting, the collected material was properly identified and taken to the Laboratory of Anatomy and Ecological Physiology of Plants and weighed for later determination of the dry matter production of the forage.

To determine pre-drying, the identified material was weighed as a green sample and after pre-drying in a forced circulation oven at 55 °C for 72 hours, it was ground in a Wille type mill to approximately 1 mm. After grinding, the final dry matter was determined, following the methodology developed by Detmann et al. (2012).

To evaluate the roots, in addition to the dry matter, the volume was determined. For this purpose, a test tube with a known quantity of water was used, where the fresh root was introduced and, through the difference in observed volume, the root volume was obtained.

To evaluate the bromatological composition, the levels of crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, hemicellulose and lignin were determined according to Detmann et al. (2012).

The estimated total digestible nutrient levels (TDN) were calculated according to Capelle et al. (2001) with the following equation:

$$TDN_{est} = 74.49 - 0.5635*ADF$$

Statistical analysis

The data obtained were analyzed using the statistical program SAS - Free Statistical Software, SAS University Edition. Analysis of variance was performed, considering the limestone source, regrowth and the interaction between the limestone source and regrowth as sources of variation. The comparison between the effects of the limestone source and regrowth were performed using the Tukey test. $\alpha = 0.05$ was adopted.

RESULTS AND DISCUSSION

The interaction was not significant ($P > 0.05$) for soil pH and base saturation observed in the 0 to 20 cm layer (Table 1). The pH was influenced ($P < 0.05$) individually by liming and the regrowth period, where for the regrowth period, the highest pH values observed occurred in the 1st and 2nd regrowth. For the purpose of liming, conventional limestone was more efficient in increasing soil pH up to a maximum value of 5.39.

pH plays a very important role in the soil, as it determines the availability of nutrients, in addition to the assimilation of nutrients by plants. The addition of limestone to the soil reduces the absorption capacity of anions, increasing biological activity and the mineralization of organic components, thus causing an increase in pH and crop productivity (Sousa, 2017).

The decrease in pH that occurred in the 3rd regrowth can be explained by the amount of nitrogen fertilization applied, since the third application occurred in the 3rd regrowth, and as observed by Costa et al., 2008, during the transformation in the soil, the nitrification process occurs, in which the ammonium ion is converted to the nitrate ion, where the nitrogen fertilizers release H+ ions into the soil solution, thereby causing a reduction in pH.

David et al. (2018) in a comparative study between liquid and conventional limestone in soil correction, with 4 treatments, namely: conventional limestone, conventional limestone + liquid limestone, liquid limestone and control, concluded that conventional limestone was superior to liquid limestone in increasing pH.

Similar results were found by Mantovanelli et al. (2019), in which they evaluated the efficiency of different doses of liquid limestone over time compared to powdered limestone in correcting pH. These authors observed that liquid limestone was inefficient, with its action limited to the first 14 days of incubation, thus stating that liquid limestone could only be used as a complement to conventional limestone, as the latter presents a reaction and residual effect for longer periods. However, divergent results were observed by Nascente & Cobucci (2015), who had favorable responses in the application of liquid limestone in increasing the pH and production of the coffee crop.

Saturation was influenced ($P < 0.05$) individually by liming and the regrowth period (Table 1), where for the regrowth period, the highest saturation was observed in the 1st, reaching 45%. For the treatment effect, conventional limestone performed better in increasing base saturation, managing to raise the initial value of 34% to the 45% desired for *Brachiaria brizantha* cultivation.

Table 1. Effect of liming and regrowth on soil pH and base saturation (V%) observed in the 0 to 20 cm layer

Variables	Regrowth			Liming			CV[1]	*P*- value		
	1ª	2ª	3ª	Controllole	Conven-tionalional	Liquidido		R	L	R_xL
pH	5.21 a	5.2 a	5.0 b	5.0 b	5.4 a	5.0 b	3.9	0.0220	< .0001	0.8587
V%	45.54 a	41.1 ab	35.4 b	35.4 b	48.6 a	38.0 b	16.8	0.0044	0.0001	0.8921

[1]Coefficient of variation in percentage. R = Regrowth; L = Liming; RxL = interaction between factors. Means followed by the same letter, in the same line, do not differ from each other by the Tukey test ($P > 0.05$).

When a certain level of desired base saturation is defined (expected V or Ve), the aim is to achieve ideal pH levels that benefit good root development and adequate nutrient availability, in addition to the supply of Ca and mg from limestone sources, with the aim of achieving high production of the crop of interest (Guarçoni, 2017).

Liquid limestone showed a small increase in saturation in the 1st regrowth, presenting a low residual effect, since for the 2nd and 3rd regrowth, high reductions in saturation were observed due to its low capacity to increase pH at the dose recommended by the manufacturer.

This behavior in decreasing pH and reducing saturation observed mainly in the 3rd regrowth, occurs due to the positive correlation between these variables, where soil pH increases or decreases proportionally and concomitantly with base saturation (Batista et al., 2015; Silva et al., 2007).

Alves (2015) in a study aimed at evaluating the effect of applying different levels of liquid limestone on the chemical attributes of soils cultivated with *Brachiaria brizantha* cv. Marandu and *Panicum maximum* cv. Mombaça, also did not observe changes in soil base saturation at doses of 5, 10 and 15 times the limestone requirement used.

The interaction was not significant ($P > 0.05$) for the production of dry mass of aerial part, residue and root, as well as for leaf/stem ratio and root volume (Table 2). The production of aerial part was influenced ($P < 0.05$) by the regrowth period, where the highest production occurred in the 1st regrowth.

Table 2. Effect of liming and regrowth on the production of shoot dry mass (PMSPA), residue dry mass (PMSRE), root dry mass (PMSRA), leaf/stem ratio and root volume of *Brachiaria brizantha* cv. Braúna

Variables	Regrowth			Liming			CV[1]	*P*- value		
	1ª	2ª	3ª	Controllole	Conven-tionalional	Liquidido		R	L	R_xL
PMSPA[2]	856.9 a	530.2 b	452.4 b	629.0 a	600.2 a	610.3 a	22.3	< .0001	0.8729	0.2860
PMSRE[2]	585.1 b	568. b	1191.7 a	849.9 a	779.4 a	716.3 a	19.9	< .0001	0.1294	0.2963
PMSRA[2]	571.8b	822.5b	1135.6 a	555.9 b	1241.4a	732.5b	27.4	0.0013	< .0001	0.1075
Razão	2.4b	2.4 b	3.6 a	2.8 a	2.8 a	2.a	15.9	< .0001	0.8704	0.2235
Volume de	160.0 b	198.8	224.2 a	181.7a	207.5 a	193.7a	20.2	0.0018	0.2903	0.8606

[1]Coefficient of variation in percentage. 2 kg ha^{-1}. 3 L. R = Regrowth; L = Liming; RxL = interaction between factors. Means followed by the same letter, in the same line, do not differ from each other by the Tukey test ($P > 0.05$).

The effect of regrowth on the production of dry mass of aerial parts was due to the reduction in production throughout the regrowth, a result that can be explained by the number of cuts suffered by the plants, where in the 3rd regrowth the production was lower, an effect also identified by Alexandrino et al. (2004), where they found in *Brachiaria brizantha* cv. Marandu, that frequent cuts reduce the vigor of regrowth and thus occur a reduction in the production of dry mass.

The leaf/stem ratio was influenced ($P < 0.05$) by regrowth, where it was noted that the highest ratio occurred in the 3rd regrowth. The higher the ratio, the greater the proportion of leaf in relation to the stem, thus implying a forage with greater nutritional value. This increase is explained by the growth dynamics of the biomass of the aerial part, since with a lower stem elongation rate, there is an increase in leaf density, which results in a higher ratio. A higher leaf/stem ratio is a desirable aspect, since the leaf is one of the morphological components with the best nutritional value (Fonseca & Santos, 2009).

The production of dry mass of residue was influenced ($P < 0.05$) by the regrowth period, with the highest production occurring in the 3rd regrowth. The observed result shows a relationship with the production of the aerial part, where the opposite effect occurred, with the cutting height being 10 cm in all cuts performed. As mentioned above, the highest production of residue observed in the 3rd regrowth implies in the lower development of stem and leaf, which leads to a higher production of biomass below the initially recommended cutting line.

Root production was influenced ($P < 0.05$) by the regrowth period and soil treatment. It was observed that for the regrowth period, the highest production occurred in the 3rd regrowth, and in liming, conventional limestone presented the highest production when compared to the other treatments.

During the regrowth, an increase in root production was observed. This result is explained by the time and quantity of regrowths that the plant was induced to produce. The lowest root production, which occurred in the 1st and 2nd regrowth, occurred because the plants remained in the experiment for 21 and 42 consecutive days, respectively, after the standardization cut. The highest production, which occurred in the 3rd regrowth, was obtained because the plants remained in the pots for 63 days after the standardization cut, thus having the possibility of having a longer-lasting root development.

As for the effect of the treatment on root production, it was observed that the treatment that received conventional limestone showed greater production, with approximately 50% more when compared to liquid limestone and the control. Therefore, it is possible to state that conventional limestone was efficient in correcting soil acidity, as observed in Table 3, which influenced the greater production of dry root mass.

Liming has a great influence on plant growth and root development, through the effect of liming in reducing Al and Mn toxicity that restrict root growth and through the greater efficiency of the root in fixing N2 by the plant, which allows greater development of the root system (Leite et al., 2006; Heinrichs et al., 2008).

Table 3. Effect of liming and regrowth on the chemical composition of *Brachiaria brizantha* cv. Braúna

Variables	Regrowth			Liming			CV	*P*- value		
	1ª	2ª	3ª	Controle	Conven-cional	Líquido		R	C	R_xL
DM (%)	21.3ab	20.9 b	23.2a	22.6 a	21.4 a	21.4a	9.5	0.0293	0.3085	0.2989
CP (%)	11.9 a	10.3 b	10.2 b	10.9 a	10.5 a	10.9 a	7.6	< .0001	0.2517	0.0638
NDF (%)	65.5 c	70.3 b	72.9 a	69.3 a	70.9 a	68.4 a	3.5	< .0001	0.0549	0.2122
FDA (%)	33.2 b	36.6 a	35.8 a	35.4 a	35.8 a	34.6 a	5.6	0.0005	0.3131	0.6553
NDT_{est} (%)	55.8 a	53.8 b	54.3 b	54.6 a	54.3 a	55.0 a	2.0	0.0005	0.3131	0.6553
Cellulose (%)	29.4 b	32.9 a	31.8 a	31.3 a	32.2 a	30.6 a	5.6	< .0001	0.1150	0.4741
Hemicellulose	32.3 b	33.6 b	37.0 a	33.9 a	35.1 a	33.9 a	3.8	< .0001	0.0530	0.0541
Lignin (%)	2.2 a	1.9 a	2.3 a	2.4 a	1.9 a	2.1 a	29.1	0.4002	0.1183	0.6682

[1]Coefficient of variation in percentage. R = Regrowth; L = Liming; RxL = interaction between factors. Means followed by the same letter, in the same line, do not differ from each other by the Tukey test ($P > 0.05$).

The importance of root development in plant growth occurs through the fixation of the plant in the soil and the extraction of water and nutrients. Thus, it is possible to observe the productivity of crops that have rapid development of the root system, since its occupation in the different layers of the soil, length and volume, are responsible for changes in the productivity of the aerial part of the forages (Corsi et al., 2001).

In a study carried out by Oliveira et al. (2000), with the objective of evaluating the development of *Brachiaria brizantha* cv. Marandu subjected to different soil fertility corrections, they found that root development occurred as a function of soil fertility, where the addition of limestone modified the original moisture and fertility conditions observed in the soil, being capable of influencing the conditions of production of root dry mass in relation to the other treatments.

The volume was influenced ($P < 0.05$) by the regrowth period, the highest value of which was observed in the 3rd regrowth, with 224.17 mL, a fact explained by the days that the treatments remained in the pots, where the 1st and 2nd regrowth had shorter times for their development.

Unlike the behavior observed for the production of root dry mass, where conventional limestone showed better performance, the root volume did not show any difference ($P > 0.05$) between treatments. This fact can be explained by the effect of acidity on the roots, where it is known that one of the effects of aluminum on plants is the thickening of the tip of their roots, which can also present yellowish, degenerated, tortuous tips, with secondary branching and a decrease in nutrient-absorbing hairs (Miguel et al., 2010). Therefore, even with lower root production for the liquid limestone and control treatments, they presented a similar volume to the roots of conventional limestone, due to the thickening of their roots.

The interaction between the regrowth period and liming was not significant ($P > 0.05$) for any of the variables evaluated in the bromatological composition of *Brachiaria brizantha* cv. Braúna (Table 3). Regrowth influenced ($P < 0.05$) the contents of dry matter, crude protein, NDF, ADF, TDN, cellulose and hemicellulose. On the other hand, the lignin content was not influenced ($P > 0.05$) by either liming or regrowth.

The chemical composition is capable of providing indicators of the productive potential of forage plants, so that adequate management can be carried out to make the best use of the forage; knowledge of the variations in the different phenological stages is one of the factors to be considered (Abreu et al., 2004).

For dry matter, NDF and hemicellulose contents, the highest values were observed in the 3rd regrowth, with 23.17%, 72.88% and 37.04%, respectively. Analyzing the ADF and cellulose contents, it was observed that the value was higher for the 2nd and 3rd regrowth. However, the crude protein and the estimated total digestible nutrients (NDTest) showed an inverse behavior in relation to that observed in the other components, with a reduction in the last two regrowths, agreeing with the results verified by Santana et al. (2010), who observed that as the plant was cut, in each growth period there was a reduction in the protein content, where there was also no influence of soil correctives on the bromatological composition of *Brachiaria*.

This result can be explained by the maturity stage, since differences in the composition of forages are observed with increasing plant age, which are reflected in an increase in indigestible fractions such as NDF and ADF, and as observed by Costa et al. (2007), the closer to maturity, the greater the decrease in water content, thus increasing dry matter content.

CONCLUSIONS

It is recommended to use conventional limestone as the main product for correcting acidity and increasing base saturation, since these characteristics are improved, and there is greater development of the roots of plants that have their soil corrected by this corrective, a fact not observed when the limestone source used is liquid.

Brachiaria brizantha cv. Braúna is influenced by regrowth in successive cutting intervals of 21 days, with a reduction in its productivity with each cut, acting mainly on the reduction of crude protein and reduction of the aerial part.

No significant effect of liming was observed on the bromatological composition, suggesting that regrowth age had a more pronounced influence on forage quality than the source of limestone. Therefore, the use of conventional limestone is recommended for effective soil acidity correction, and careful management of cutting intervals is necessary to balance forage yield and nutritional value in systems using *Brachiaria brizantha cv. Braúna*.

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