Scientific Paper

# Agronomic evaluation of forages with inclusion of dolomite amendment in Nariño, Colombia

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## Abstract

**Objective**: To evaluate the effect of dolomite amendment on the forage yield in the rainy and dry season in Nariño, Colombia.

**Materials and Methods**: A trial was conducted at the Obonuco research center (AGROSAVIA). A split-plot design in complete randomized blocks was developed, with 18 treatments and three repetitions, for a total of 54 experimental units. The green forage, dry matter and pH, were evaluated. Variance analysis was carried out and Tukey's test was applied to establish significant differences ($p \leq 0{,}05$). The obtained information was analyzed through the program R V.3.6.1.

**Results**: In the rainy season significant differences ($p < 0{,}001$) were found for the green forage and dry matter yield, in favor of the association of *Dactylis glomerata* L. + *Trifolium repens* L. + *Trifolium pratense* L., with values of 1 817 and 2 922 kg ha$^{-1}$, respectively. In the dry season, differences ($P < 0{,}05$) were found for the green forage and dry matter yields. The mixture of *Lolium perenne* L + *T. repens* showed values of 13 312,2 kg ha$^{-1}$ and 2501,3 kg ha$^{-1}$ respectively. In the evaluated period no differences were observed for pH among the treatments.

**Conclusions**: For the rainy and dry seasons, the associations of *D. glomerata* + *T. repens* + *T. pratense* and *L. perenne* + *T. repens* favored the yields at the harvest age of 35 days.

**Keywords**: dolomite, grasses, legumes, green forage

## Introduction

In the world, the tropical zone represents 20 % of the land, and 40 % of the useful land for the human being. Additionally, the climate provided by the tropical zone favors agrobiodiversity and supports the feeding of more than 40 % of the world population. For such reason, the tropic represents an alternative for the production of foodstuffs of animal origin. Pastures and forages constitute the feeding basis of the animals in this region; although they show high biomass production, it occurs seasonally (UNEP-WCMC, 2016).

The Colombian tropic is a zone with abundant and frequent rainfall at several times of the year. In this region, more than 85 % of the soils aimed at forage production are classified as acid (Malagón-Castro, 2003).

In Colombia, animal husbandry has been developed with introduced plant species, generally not adapted to the conditions of the region, highly dependent on inputs, and to which inappropriate techniques have been applied, causing depleted, eroded and very acid soils, conditions that limit pasture production (Moncada-González *et al*., 2016).

With some exceptions, the best pH range for the growth of most plants is between 5,5 and 6,5 for some ryegrasses especially and, mainly, for legumes (Cobo-Lemos, 2003). In order to ensure the conditions required by these species, farmers have invested large quantities of money attempting to change the acidity conditions in the soils aimed at planting, and thus adapting them to sustain the highly pH demanding crops (Moncada-González *et al*., 2016).

Soil acidity is corrected with the application of limestone. In most cases, limestone application increases the Ca, Mg and P contents of the forage, especially when it is done with dolomitic limestone (Villaneda-Vivas and Sánchez-Matta, 2009).

The application of increases limestone doses increases the pH values and biomass production, independently from the forage species (Combatt *et al*., 2008).

The area dedicated to forage production is 10 103 ha. From them, 20,2 % corresponds to *Lolium*

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*perenne* L.; 27,5 % to natural or naturalized forages; 36,4 % to mixtures of naturalized pastures, such as *Dactylis glomerata* L., *Cenchrus clandestinus* (Chiov.) Morrone and *Halcus lanatus* L. In lower percentage (15,9 %) there are grasslands of *Medicago sativa* L., *Phalari, Trifolium pratense* L. and *Trifolium repens* L. mixed with the above-mentioned pastures. According to Mejía-Zambrano (2012), in the use of grasslands there are deficient management practices and low technification.

From these conditions, in order to offer a recommendation that guarantees the adequate use of the amendment, and which does not generate the loss of economic resources due to the application of the inadequate dose, the objective of this study was to evaluate the effect of dolomite amendment on forage yield in the rainy and dry seasons, in Nariño, Colombia.

## Materials and Methods

*Location*. The study was conducted between December, 2017, and September, 2018, at the Obonuco research center, property of the Colombian Corporation of Agricultural Research (AGROSAVIA). The facility is located in the Pasto municipality, Nariño, Colombia, at 2 905 m.a.s.l. (1° 88' 918" N and 77° 306' 083" W).

*Edaphoclimatic conditions*. The average annual rainfall of the region is 1 273 mm and the average temperature, of 13,8 ºC. The origin of its soils is volcanic ash and they belong to the texture group sandy loam (Climate-Data.org, 2018). There are two well-defined seasons in this zone (figure 1): rainy season (March, April and May) and dry season (June, July and August).

*Experimental design and treatments*. The trial was established through a split-plot design in complete randomized blocks, with 18 treatments and three repetitions, for a total of 54 experimental units. In the main plot the effect of six mixtures of grasses and legumes was evaluated and in the subplots, the effect of three amendment doses (10, 5 and 2 t). Each experimental unit had a size of 9 $m^2$ for a total area of 760,5 $m^2$. The treatments resulted from the interaction of the two factors (table 1).

*Experimental procedure*. Six forage types (table 2) were established, composed by *L. perenne*, Tetrablend 260 (commercial mixture made up by 30 % annual tetraploid *L. perenne*; 50 % hybrid tetraploid *L. perenne*, 10 % *D. glomerata* and 10 % *T. pratense*) and *D. glomerata*, with the legumes *T. repens* and *T. pratense*. In addition, three doses of dolomite amendment, which is a combination of calcium carbonate and magnesium [$CaMg(CO_3)2$],

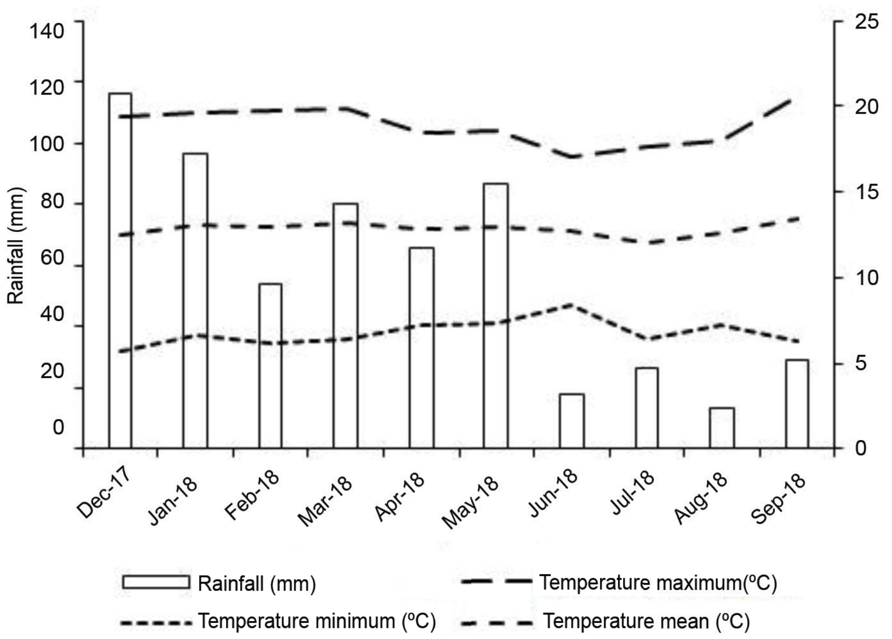


Figure 1. Accumulated rainfall and temperature in December, during the study.
Source: Station Vintage pro 2, Colombian Corporation of Agricultural Research (AGROSAVIA). Pasto, Colombia

Table 1. Evaluated treatments.

| Treatment | Dose of Ca $Mg(CO_3)_2$, t | Forages |
|---|---|---|
| T1 | 10 | *L. perenne* |
| T2 | 10 | *L. perenne* + *T. repens* L |
| T3 | 10 | *L. perenne* + *T. pratense* L |
| T4 | 10 | *L. perenne* + *T. repens*+ *T. pratense* |
| T5 | 10 | *D. glomerata* L + *T. repens*+ *T. pratense* |
| T6 | 10 | Commercial mixture (Tetrablend 260) |
| T7 | 5 | *L. perenne* |
| T8 | 5 | *L. perenne* + *T. repens* L |
| T9 | 5 | *L. perenne* + *T. pratense* L |
| T10 | 5 | *L. perenne* + *T. repens*+ *T. pratense* |
| T11 | 5 | *D. glomerata* + *T. repens*+ *T. pratense* |
| T12 | 5 | Commercial mixture (Tetrablend 260) |
| T13 | 2 | *L. perenne* |
| T14 | 2 | *L. perenne* + *T. repens* |
| T15 | 2 | *L. perenne* + *T. pratense* |
| T16 | 2 | *L. perenne* + *T. repens* + *T. pratense* |
| T17 | 2 | *D. glomerata* + *T. repens*+ *T. pratense* |
| T18 | 2 | Commercial mixture |

Table 2**.** Annual and perennial forages *L. perenne*, Tetrablend 260 (commercial mixture) and *D. glomerata*, with the legumes *T. repens* y *T. pratense* and planting densities (kg $ha^{-1}$).

| Mixture | *L.perenne* | *T.repens* | *T.pratense* | *D. glomerata* | Tetrablend 260 |
|---|---|---|---|---|---|
| 1 | 28 | 3 | - | - | - |
| 2 | 28 | - | 6 | - | - |
| 3 | 28 | 3 | 6 | - | - |
| 4 | - | 3 | 6 | 25 | - |
| 5 | - | - | - | - | 30 |
| 6 | 28 | - | - | - | - |

were used. Doses of 10, 5 and 2 t $ha^{-1}$ were established. The second dose was determined based on the results of the soil analysis, and the other two, according to the trials conducted in New Zealand by Edmeades *et al*. (2012).

The land preparation was done with vibratory chisel plow and heavy harrow twice. Dolomitic limestone was applied according to the established doses (10, 5 and 2 t) per experimental unit and it was incorporated for one month, approximately. Fertilization was manually carried out, in a fractioned way, at the moment of planting, with 50 kg of $P_2O_5$ $ha^{-1}$. Five months later 150 kg of N $ha^{-1}$, 50 kg of $P_2O_5$ $ha^{-1}$, 40 kg of $K_2O$ $ha^{-1}$, 30 kg of Mg $ha^{-1}$ and 30 kg of S $ha^{-1}$ were applied. Irrigation was performed taking into consideration the monthly water balance. The water blades were applied through stationary irrigation on wheels (NUMEDIC). As hydric source, the surface water of a torrential type stream was used.

*Evaluated variables*. To measure the variables, the methodology proposed by Toledo (1982) was adapted, with 15-day frequency. The green forage (GF) and dry matter (DM) yield and pH, were evaluated.

*GF yield, kg ha$^{-1}$*. In the three evaluation cycles, to determine the green forage yield a cut was performed at 35 d. The forage present within a framework of 0,25 m$^2$ was cut and weighed on a VIBRA digital scale, model AB3202.

*DM yield, kg ha$^{-1}$*. From each green forage sample a 500-g subsample was taken. They were put in paper bags in a Memmert universal drying oven, model UF 260, at 65 °C during 72 h.

*pH*. It was measured every two months, between April and September, 2018, using a Consort C5020 portable pH meter. The protocol developed by the University of Nariño (Delgado and Jurado, 2016) was applied.

*Mathematical analysis*. Variance analysis was done, with previous testing of the variance homogeneity and data normality assumptions. Tukey's test was applied to establish significant differences ($p \leq 0,05$). The information was analyzed through the program R V.3.6.1 (R Development Core Team, 2008) using the agricultural packages (Mendiburu, 2017) and ggplot2 (Wickham, 2016).

## Results and Discussion

*GF and DM yield*. During the rainy season no statistical differences were found (P = 0,966) between the interactions of the two factors, for which the main factors were analyzed separately. For the factor forage significant differences were found in the variables GF and DM yield. The associations *D. glomerata* + *T. repens*+ *T. pratense* and *L. perenne* + *T. repens*+ *T. pretense* showed the best averages, without significant differences between them (table 3).

When evaluating the mixture of *D. glomerata* + *L. perenne* + *T. pratense*, Rojas-García *et al*. (2016) found DM yields of 3 243 kg/ha$^{-1}$ in the rainy season, similar values to the one obtained in this study. This could have been possibly due to the DM contribution of *T. repens* and *T. pretense* in the association, as well as to the evaluation season.

Lucero *et al*. (2002) state that these species, under adequate humidity conditions, have higher capacity of $N_2$ symbiotic fixation and higher transference of this element to the companion grass. Brophy *et al*. (2017) and Solati *et al*. (2018) suggest that legumes influence positively the forage yield and are considered a potential protein source.

For the dry season no statistical differences were found between the interactions of two factors, for which the effect of the principal factors was analyzed separately (table 4). It was observed that for the factor forage significant differences appeared in the variables of GF and DM yield, where the association of *L. perenne* + *T. pratense* reached 13 312,2 and 2 501,3 kg ha$^{-1}$, respectively.

Maldonado-Peralta *et al*. (2007) reported a DM yield for *L. perenne* of 4 815 kg DM ha$^{-1}$ for the summer, which proves that perennial pastures perform well during this season.

Nava-Berumen *et al*. (2018) found GF and DM yields of 29 500 and 6 500 kg ha$^{-1}$ in *L. perenne* during the dry season, in a soil with pH 7,9 (moderately alkaline). These values were higher than those in this study, which is explained by the high influence of alkalinity on forage production. In addition, the above-cited authors recommend *L.*

Table 3. GF and DM yield in the rainy season, at 35 days of age.

| Treatments | Yield, kg ha$^{-1}$ | |
|---|---|---|
| | GF | DM |
| *L. perenne* | 7 947,1$^{d}$ | 1 812,1$^{c}$ |
| *L. perenne* + *T. repens* | 14 313,8$^{bc}$ | 2 347,7$^{b}$ |
| *L. perenne* + *T. pratense* | 12 551,7$^{bc}$ | 2 274,1$^{b}$ |
| *L. perenne* + *T. repens*+ *T. pratense* | 15 535,3$^{ab}$ | 2 432,8$^{b}$ |
| *D. glomerata* + *T. repens*+ *T. pratense* | 18 178,3$^{a}$ | 2 922,1$^{a}$ |
| Commercial mixture(Tetrablend 260) | 11 409,3$^{cd}$ | 2 333,8$^{b}$ |
| SE ± | 0,416 | 0,049 |

a, b, c and d: means with different letters in the same column differ among them, according to Tukey's test for p < 0,05

Table 4. GF and DM yield of six forages, evaluated in the dry season, at the age of 35 days.

| Species | Yield, kg ha$^{-1}$ | |
|---|---|---|
| | GF | DM |
| *L. perenne* | 8 907,7$^{c}$ | 1 895,7$^{b}$ |
| *L. perenne* + *T. repens* | 11 282,5$^{abc}$ | 1 959,0$^{b}$ |
| *L. perenne* + *T. pratense* | 13 312,2$^{a}$ | 2 501,3$^{a}$ |
| *L. perenne* + *T. repens*+ *T. pratense* | 13 008,5$^{ab}$ | 2 288,3$^{ab}$ |
| *D. glomerata* + *T. repens*+ *T. pratense* | 10 254,4$^{bc}$ | 1 863,2$^{b}$ |
| Commercial mixture (Tetrablend 260) | 9 361,9$^{cd}$ | 1 932,9$^{b}$ |
| SE ± | 0,382 | 0,057 |

a, b, c and d: means with different letters in the same column differ among them, according to Tukey's test for $p < 0,05$

*perenne* varieties in combination with other species to produce quality forage in dry seasons. They state that this mixture constitutes an alternative for obtaining GF, with low productivity in the first cuts and high in the last ones. Villalobos and Sánchez (2010) state that the biomass production of *L. perenne* significantly increases in the season of higher solar radiation, and is maintained relatively constant the rest of the year.

In this study, the amendment doses did not affect yield, but the forage species, season (high and low rainfall) and evaluation time (1 year) did affect it. Tomić *et al.* (2018) evaluated the application of 3 and 6 t ha$^{-1}$ of CaO in *T. pratense* and oat (*Avena sativa* L.), and found higher DM yield and content in the third year of evaluation, due to limestone application, because this amendment helps reduce the quantity of mobile and toxic forms of aluminum, iron and manganese, which increases the quantity of phosphorus available in the soil for clovers and pastures.

*Variable pH.* No statistical differences appeared among the pH values with the three limestone doses applied (fig. 2). The application of calcareous amendment increased the initial pH of the soil (5,8) to values of 6,08; 6,16 and 6,32 with the application of doses of 2, 5 and 10 t ha$^{-1}$ of dolomitic limestone, respectively.

This performance appeared perhaps due to the high buffer capacity of these soils. This causes that pH does not increase significantly, even with the application of amendments, due to the mineralogy of pH-dependent variable charge clays that characterizes these acid soils (Garbanzo-León *et al.*, 2016).

This performance appeared perhaps due to the high buffer capacity of these soils. This causes that pH does not increase significantly, even with the application of amendments, due to the mineralogy of pH-dependent variable charge clays that characterizes these acid soils (Garbanzo-León *et al.*, 2016).

The referred results do not differ from the ones reported by Demanet-Filippi (2017), who states that to increase 0,7 points of pH 3,3 t ha-1 of dolomitic limestone are required. And they are similar to those reached by Carvajal *et al.* (2016), who obtained increases of 0,37 points in pH 80 days after planting (from 5,6 to 6,0), with the application of 3 t ha-1 of dolomitic limestone.

Possibly, the performance observed here is due to the fact that dolomitic limestone helps reduce soil acidity, by increasing the pH units. These products dissolved in the soil produce OH ions, which when combined with $H^{+}$ are neutralized, and by their reaction $H_2O$ is produced. OH ions also react with $Al^{+++}$ in the soil solution, precipitating it as $Al(OH)_3$. Thus, $Al^{+++}$ becomes inert (Carvajal *et al.*, 2016).

## Conclusions

For the dry and rainy seasons, the associations with *D. glomerata* + *T. repens*+ *T. pratense* and *L. perenne* + *T. repens* favored the yields at the harvest age of 35 days. In addition, the amendment dose did not affect forage yield or pH.

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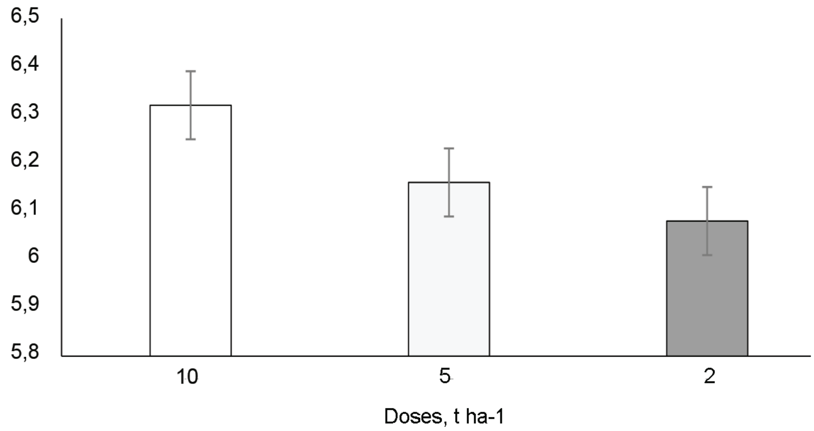


Figure 2. Soil pH values according to the dolomite doses [$CaMg (CO_3)_2$]

## Authors' contribution

- Jenny Jackeline Zapata-Molina. Design of the methodology, research development, writing of the original draft, manuscript revision and edition.
- Paola Andrea Portillo-López. Design of the methodology, research development, writing of the original draft, manuscript revision and edition.
- Diego Hernán Meneses-Buitrago. Design of the methodology, data analysis, manuscript revision and edition.
- Edwin Castro-Rincón. Design of the methodology, manuscript revision and edition
- Elizabeth Lagos-Burbano. Design of the methodology, manuscript revision and edition.

## Conflict of interests

The authors declare that there are no conflicts of interests among them.

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