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Scientific Paper

Evaluation of grassland renovation methods in the high tropic of Nariño, Colombia

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Abstract

Objective: To evaluate the effect of different grassland renovation methods on the *Lolium* sp. productivity during rainy and dry seasons in the high tropic of the Nariño department.

Materials and Methods: The essay was conducted between January and August, 2018. Two experiments were established in the Pasto and Sapuyes municipalities. An experimental design of complete randomized blocks was used, with five treatments and three replicas (T1: farmer's conventional management; T2: grassland renovator; T3: harrowing twice; T4: rigid chisel plow once, harrowing once and subsoiling once; T5: vibratory chisel plow once and harrowing once). The variables cover percentage, height, green forage and dry matter yield, were evaluated. For the statistical analysis, the software R V 3.5.1 was used. Variance analysis and Tukey's test were carried out for comparison among means ($p < 0{,}05$).

Results: In the rainy season, in the Pasto locality, the variable plant height showed significant differences among treatments ($p < 0{,}001$). T5 showed the highest value (38 cm). In turn, significant differences were found in the green matter and dry matter yield among treatments, T3 being the one with the best performance (16,2 and 2,6 t ha^{-1}, respectively). In the Sapuyes locality, T1 reached the best results for the variables cover percentage, plant height, green forage and dry matter yield (96,0 %; 67,5 cm; 34,2 t ha^{-1} and 4,19 t ha^{-1}, respectively). In the dry season, in the Sapuyes locality, the variable green forage yield showed significant differences among treatments, T1 being the most outstanding one (21,1 t ha^{-1}).

Conclusions: During the rainy and dry seasons, T3 reached the best values in green forage and dry matter yield for the Pasto locality; while for Sapuyes, T1 showed the best values.

Keywords: *Lolium*, grassland renovation, green forage, dry matter

Introduction

The animal husbandry sector occupies the highest percentage of agricultural lands. The total surface represented by pastures is 26 % of the ice-free surface (FAO, 2019). In Latin America, Brazil is the main milk producer, with 33 620 million liters per year, followed by such countries as Argentina, Mexico and Colombia. The last one occupies the fourth place, with production of 6 550 million liters per year and average annual growth of 100 000 liters since 2012, for which it contributes with 2 % of the national GDP and 24,3 % of the agricultural GDP, generating more than 700 000 direct jobs (MADR and MINCIT 2016)[1]. Milk production is present in 22 departments, Antioquia being the main producer with 3,5 million liters per day (Pinto, 2017), followed by Boyacá, Cundinamarca and Nariño. The last one, with a production of 982 thousand liters per day, is part of the most outstanding dairy basins of the country (SAGAN, 2018).

The Nariño department is located in the agroecological zones of the high Colombian Andean tropic. It has particular microclimate characteristics which favor specialized milk production. According to the Animal Production and Health Research Group (Grupo de Investigación en Producción y Sanidad Animal, 2009), the area dedicated to forage production is estimated in 10 103 ha, from which 20,2 % corresponds to annual or perennial ryegrasses (*Lolium* sp.); 27,5 % to natural or naturalized forages; 36,4 % to mixtures of naturalized pastures, such as cock's foot (*Dactylis glomerata* L.), kikuyu [*Cenchrus clandestinus* (Hochst. ex Chiov.)] and Yorkshire fog *(Holcus lanatus* L.). In lower percentage (15,9 %) are the alfalfa (*Medicago sativa* L.),

[1]MADR: Ministry of Agricultural and Rural Development
MINCIT: Ministry of Commerce, Industry and Tourism

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Brazilian grass (*Phalaris* sp.) and clover (*Trifolium* sp.) grasslands, which are mixed with the above-mentioned pastures. Nevertheless, the poor technical parameters of tillage and animal trampling increase dry matter (DM) losses in 90 %, degrade and modify the soil physical, chemical and biological properties (Hernández, 1992; Noreña and Galeano, 2004).

Green forage (GF) yield decreases in the dry season, which causes decrease of the carrying capacity per area unit in the pastures dedicated to milk production (Mendoza, 1992). Specialized dairy farmers in the high tropic of the Nariño department limit grassland management to crop rotation (pasture-potato-pasture), methodology that does not allow the recovery of the pasture after grazing in long summer periods, which generates damage on the soil physical, chemical and biological properties (Corpoica, 1994).

Pastures, just like all crops, demand management practices to increase their production capacity. Grassland renovation, associated with mechanical methods and agronomic management, allows to increase the available GF and DM (Hernández 1992). However, it is important to plan and define the soil preparation activities, by determining exactly the methodology and agricultural machinery to be used, from the topographic conditions of the land, soil texture and consistency status.

The objective of this research was to evaluate the effect of different grassland renovation methods on the productivity of *Lolium* sp. during rainy and dry seasons in the high tropic of Nariño department, Colombia.

Materials and Methods

The study was conducted in the Pasto and Sapuyes localities, of the Nariño department, Colombia. The coordinates, altitude and soil conditions are shown in table 1.

Figures 1 and 2 show the cumulative rainfall and daily mean temperature, from January to August, 2018. This information comes from the meteorological station Vantage Pro 2, for the Pasto and Sapuyes localities, respectively.

Treatments and experimental design. The experiments were established in a complete randomized block design, with ffive treatments and three replicas (table 2). T1 consisted in the farmer's conventional management, who sows potato (*Solanum tuberosum* L.) as predecessor crop through the *guachado* technique, four months before the establishment of the *Lolium* sp. cultivars. T2 was based on the grassland renovator, in order to break the first 30 cm of soil. In T3 the heavy harrow was used twice, in order to break the first 15 cm of soil and destroy and incorporate the existing material. T4 was characterized by using the heavy harrow once to achieve later the penetration of the rigid chisel plow (the shanks of the chisel plow were separated at 30 cm) and subsoiler at 40 cm of soil. In T5, the heavy harrow, and later the vibratory chisel plow to smoothen the existing clods. Each experimental unit had an area of 400 m^2.

Experimental procedure. In each locality, 1,2 ha were renovated. The planting density of ryegrass was 50 kg ha^{-1}. Fertilization was manually applied, dividedly, at the moment of sowing and four months later, with 375 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1}, 250 kg K_2O ha^{-1} and 30 kg S ha^{-1} in each application. Different species were used, because they were the ones that showed better adaptability and development in each locality, according to the previous study conducted by Cadena-Guerero *et al*. (2019).

Establishment period. A homogenization cut was made 90 days after planting (September to December, 2017).

Four cuts were made, two in the rainy season (January to April, 2018) and two in the dry season (May to August, 2018). The evaluations were carried out with the same frequency for all the treatments. In each experimental unit sampling was conducted 45 days after cutting.

Evaluated variables. The pasture cover was evaluated in percentage of the area delimited by the 1m^2 sampling framework, and according to the scale that is shown in figure 3.

Table 1. Location of the experiments in the Pasto and Sapuyes localities, Nariño, Colombia.

Municipality	Locality	Coordinates	Altitude, m a.s.l.	Soil texture
Pasto	Research Center Obonuco, AGROSAVIA[¥]	N 01° 11' 4.13'' W 77° 19' 0.19''	2905	Sandy loam
Sapuyes	Experimental Farm Chimangual, University of Nariño	N 01° 02' 6.55'' W 77° 45' 3.88''	3157	Gravelly Sandy loam

Source: Climate-Data.org (2019).
[¥]Colombian corporation of agricultural research

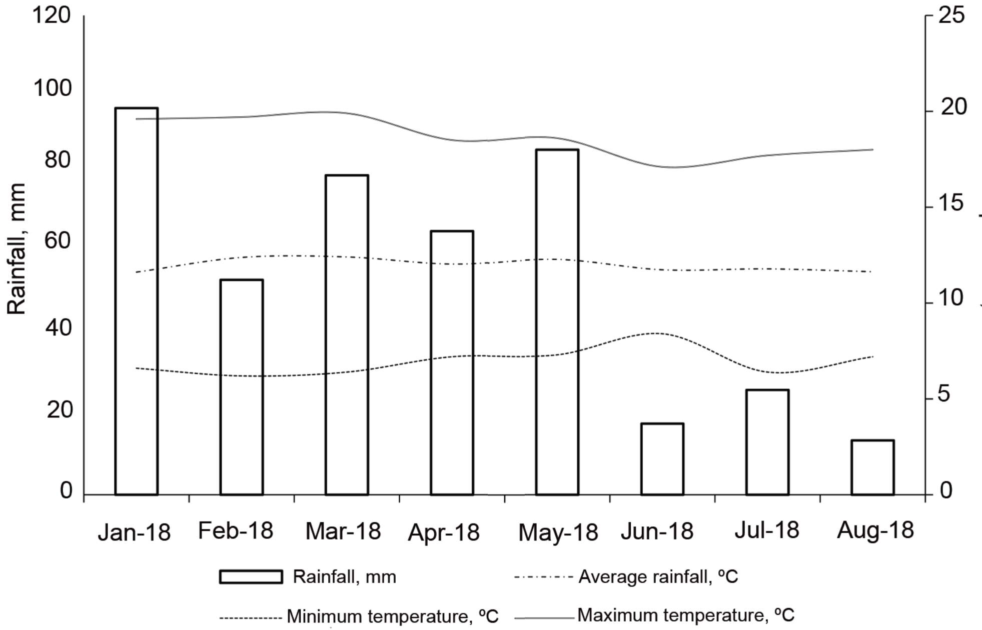

Figure 1. Cumulative rainfall from January to August, 2018, Pasto locality, Colombia.
Source Meteorological Station Vantage Pro 2

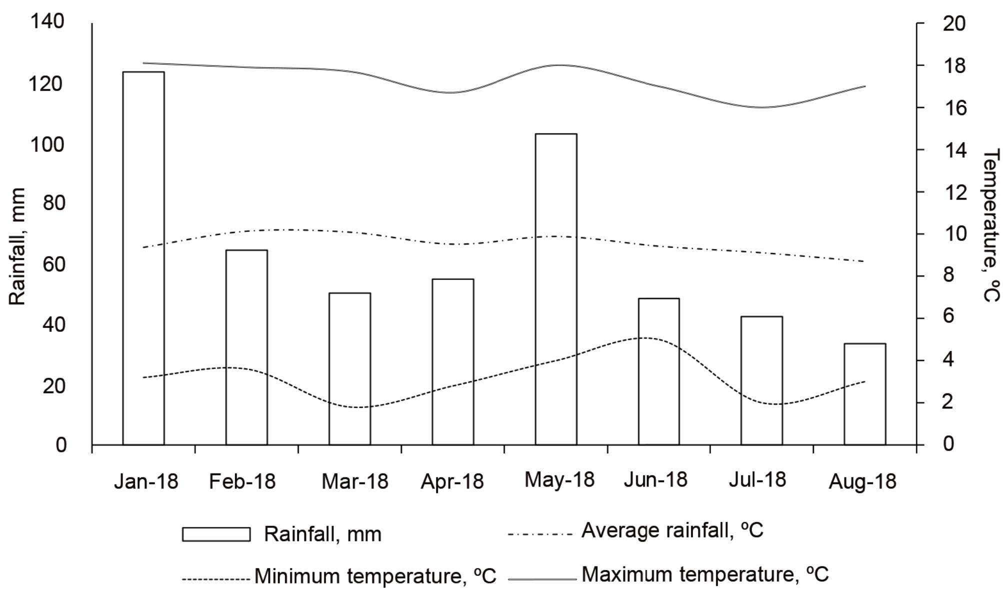

Figure 2. Accumulated rainfall from January to August, 2018, Sapuyes locality, Colombia.
Source: Estación meteorológica Vantage Pro 2

Plant height. The height of five plants, randomly selected in each experimental unit, was measured. For such purpose, a 1-m^2 sampling frame was used. The height was measured from the soil to the highest point of the plant, without stretching it and without cutting the inflorescence (Cortes and Viveros, 1975).

GF and DM yield. During the productive phase, after the homogenization cut (two in the rainy and dry seasons),

Table 2. Evaluated treatments per locality in the rainy and dry seasons in Nariño, Colombia.

Treatment	Tillage system	Locality	
		Pasture	Sapuyes
		Species	
T1	Farmer's conventional management	Potato (*S. tuberosum*), Ryegrass Columbia (*Lolium hydridum* Hausskn.)	Potato (*S. tuberosum*), Ryegrass Aubade (*Lolium multiflorum* Lam.)
T2	Grassland renovator	Ryegrass Columbia (*L. hydridum*)	Ryegrass Aubade (*L. multiflorum*)
T3	Harrow twice	Ryegrass Columbia (*L. hydridum*)	Ryegrass Aubade (*L. multiflorum*)
T4	Rigid chisel plow once, harrow once and subsoiler once	Ryegrass Columbia (*L. hydridum*)	Ryegrass Aubade (*L. multiflorum*)
T5	Vibratory chisel plow once and harrow once	Ryegrass Columbia (*L. hydridum*)	Ryegrass Aubade (*L. multiflorum*)

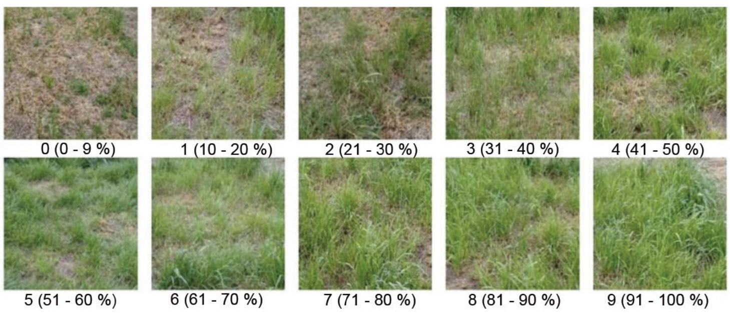

Figure 3. Scale (0-9) to determine the cover percentage in *Lolium* sp
Source: Cadena-Guerrero *et al*. (2019).

which was performed 90 days after planting, in the Pasto and Sapuyes localities, the GF yield was determined. For such purpose, in each cycle harvests were performed every 45 days, cutting the forage at 5 cm of height over the soil, in the 1-m^2 sampling frame. From each GF sample a 500-g subsample was taken. They were placed in paper bags in drying oven, at temperature of 70 ºC, during 48 h, for determining dry matter (Toledo, 1982).

Statistical analysis. The data were analyzed through the statistical program R V.3.5.6 (R Development Core Team, 2018), after testing the variance homogeneity and normal distribution assumptions. A variance analysis (ANOVA) was done, accompanied by Tukey's mean comparison test ($p \leq 0,05$). The package Agricolae (Mendiburu, 2017) was used.

Results

Rainy season. In the Pasto locality, the variable cover did not show significant differences among treatments. However, the variable plant height did show significant differences among treatments. T5 reached the highest value, with a height of 38 cm.

The vertical tillage methodology implemented in T2 did not contribute to decrease the presence of ponding after a strong rainfall event or application of irrigation due to bad drainage, which caused low germination and persistence percentage of *L. hybridum* in the grassland.

The GF and DM yield showed significant differences among treatments, being T3 the most outstanding, with 16,2 and 2,6 t ha^{-1}, respectively.

In the Sapuyes locality, T1 reached the best results for the variables cover percentage, plant height, GF and dry forage, with average values of 96,0 %; 67,48 cm; 34,2 t ha^{-1} and 4,2 t ha^{1}, respectively (table 4).

Dry season. In the Pasto locality, the variable cover percentage did not show significant differences among treatments (table 5). The height showed statistically significant differences ($p < 0,05$), with T1 standing out, with average value of 31 cm. The

Table 3. Mean values for variables evaluated in the different treatments in the rainy season, Pasto locality.

Treatment	Cover, %	Heigh, cm	Yield, t ha^{-1}	
			Green forage	Dry matter
T1	81,3	27,3^{b}	7,0^{b}	1,2^{b}
T2[¥]	-	-	-	-
T3	86,7	48,9^{a}	16,2^{a}	2,6^{a}
T4	88,9	43,3^{a}	11,2^{ab}	1,7^{ab}
T5	76,4	38,1^{ab}	11,5^{ab}	1,8^{ab}
SE ±	2,18	1,84***	1,02*	0,14**

[¥]T2 did not germinate
a, b, c means with different letters in the same column differ among them, according to Tukey's test (P ≤ 0,05), *P < 0,05, **P < 0,01, ***P <0,001
T1: farmer's conventional management, T2: grassland renovator, T3: harrowing twice, T4: rigid chisel plow – harrow – subsoiler, T5: vibratory chisel plow – harrow

Table 4. Mean values for variables evaluated in the different treatments in the rainy season, Sapuyes locality.

Treatment	Cover, %	Height, cm	Yield, t ha^{-1}	
			Green forage	Dry matter
T1	96,0^{a}	67,5^{a}	34,2^{a}	4,2^{a}
T2	27,3^{c}	41,7^{b}	9,7^{b}	1,8^{b}
T3	56,0^{b}	49,5^{b}	14,3^{b}	2,2^{b}
T4	58,2^{b}	51,9^{b}	16,1^{b}	2,4^{b}
T5	60,3^{b}	50,9^{b}	14,1^{b}	2,2^{b}
SE±	2,38***	1,47***	1,10***	0,13***

a, b, c means with different letters in the same column differ among them, according to Tukey's test (p ≤ 0,05), *p < 0,05, **p < 0,01, ***p <0,001
T1: farmer's conventional management, T2: grassland renovator, T3: harrowing twice, T4: rigid chisel plow – harrow – subsoiler, T5: vibratory chisel plow – harrow

Table 5. Mean values for variables evaluated in the different treatments in the dry season, Pasto locality.

Treatment	Cover, %	Height, cm	Yield, t ha^{-1}	
			Green forage	Dry matter
T1	51,8	31,1^{a}	4,0	1,1
T2	-	-	-	-
T3	56,4	26,3^{b}	4,1	1,2
T4	53,4	27,4^{ab}	3,8	1,1
T5	58,8	26,3^{b}	3,8	1,1
SE ±	2,94	0,63*	0,09	0,03

[¥]T2 did not germinate
a, b: means with different letters in the same column differ among them, according to Tukey's test (p ≤ 0,05), *p < 0,05
T1: farmer's conventional management, T2: grassland renovator, T3: harrowing twice, T4: rigid chisel plow – harrow – subsoiler, T5: vibratory chisel plow – harrow

GF yield and dry forage did not show significant differences among treatments.

In the Sapuyes locality, the cover showed significant differences among treatments (table 6). T1 was the most outstanding, with 97 %. The variable height showed significant differences among treatments. T1 and T3 reached the highest average values, of 64 and 63 cm, respectively.

In the GF yield there were significant differences among treatments. T1 was the most outstanding one, with 21,07 t ha^{-1}. Regarding the DM yield, no statistically significant differences among treatments were recorded.

Discussion

In the Pasto locality, the tillage type and edaphoclimatic conditions influenced the establishment and forage production, which generated differential performances in some variables in each evaluation season. The vertical tillage methodology implemented in T3 obtained the highest GF and DM yield of the ryegrass Columbia, in the rainy and dry season, compared with the other evaluated tillage systems. This performance is explained by the good aeration produced by the harrow, which improved the soil physical conditions and favored root development. In this regard, Ara (1991) states that improving the soil physical conditions through vertical tillage, guarantees good seedling emergence and vigor in the grassland.

The yields of this study are higher than the ones reported by Cadena-Guerrero *et al.* (2019) and Portillo-López *et al.* (2019), who confirm that in the rainy season there is higher GF and DM yield. According to Rodríguez *et al.* (2011), this performance responds to the fact that during the rainy season there is higher soil humidity and duration of the day, which causes plants to accumulate higher biomass quantity, and which show their growth potential and variability more dynamically.

For the evaluated treatments, the variable cover during the rainy and dry seasons is a favorable indicator of the effect of tillage system on soil porosity. Silva-Acuña *et al.* (2005) stated that tillage systems favor the horizontal growth of the pasture and significantly decrease weeds and uncovered areas.

In the Sapuyes locality, the environmental characteristics and edaphic conditions influence the DM production of *L. multiflorum* and, thus, the establishment of temperate climate species under tropical conditions of altitude. The vertical tillage system used in T1 achieved reaching the highest GF and DM yields during the rainy and dry seasons, which generates differential responses in the variables with regards to the other evaluated tillage systems.

Méndez *et al.* (2014), Zambrano-Burbano *et al.* (2014) and Vargas and Martínez *et al.* (2018) reported similar results to the ones found in this study, which ratifies that during the rainy season the GF and DM yield is higher.

Yepes and Silveira-Buckeridge (2011) state that this performance is due to the fact that rainfall remarkably influences biomass production, because of the increase of soil humidity which causes remarkable effect on pasture growth and quality. The last one is explained by the existing close relation between rainfall and the biochemical and physiological factors that regulate these biological processes.

The significant responses of T1 in the studied variables are due to the chemical fertilization applied

Table 6. Mean values for the evaluated variables in the different treatments during the dry season, Sapuyes locality.

Treatment	Cover, %	Height, cm	Yield, t ha^{-1}	
			Green forage	Dry matter
T1	96,7^{a}	63,6^{a}	21,1^{a}	2,6
T2	37,3^{c}	55,5^{b}	11,3^{c}	2,0
T3	62,0^{b}	59,2^{ab}	12,0^{bc}	2,2
T4	71,0^{b}	62,9^{a}	14,4^{bc}	2,4
T5	69,5^{b}	59,9^{ab}	15,8^{b}	2,7
EE±	2,18***	0,81*	0,57***	0,09

a, b, c means with different letters in the same column differ among them, according to Tukey's test ($p \leq 0,05$), $*p < 0,05$, $***p < 0,001$

T1: farmer's conventional management, T2: grassland renovator, T3: harrowing twice, T4: rigid chisel plow – harrow – subsoiler, T5: vibratory chisel plow – harrow to the predecessor crop, which was potato. Due to its limited root system, it extracts a portion of the nutrients that are found between 0 and 30 cm, and leaves large quantities that are used by the ryegrass Aubade (*L. multiflorum*) during its establishment. Rodríguez (1973) states that at the moment of harvesting potato just the nutrients of the surface soil layer are extracted.

The DM yields in the dry season are ascribed to the fact that the applied tillage systems did not generate high effect on the physical properties, because this soil did not receive any mechanical intervention some time ago, according to the historical records of the lot. Ceballos *et al.* (2010) state that the changes in the soil physical properties are more ascribed to the frequency and intensity of preparation activities than to the tillage method.

Ruiz-Eraso *et al*. (2002), when evaluating tillage systems of animal draught and vibratory chisel plow in andisol soils, report that these practices do not have effect on the soil physical properties or on their detriment, and neither on their improvement. According to these authors, this is due to the soil stability and short-term work. Thus, immediate effects on the GF and DM yield in *Lolium* sp. grasslands cannot be seen.

Conclusions

In the Pasto locality, T3 (harrowing twice) proved to be a method that favors green forage and dry matter production in the rainy and dry seasons, because it guarantees good root development of *L. hydridum*.

In the Sapuyes locality, T1 (farmer's conventional management) is a method that favors GF and DM yields in the rainy and dry seasons, which guarantees good nutrient availability before the establishment of *L. multiflorum*.

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Authors' contribution

- Jose Libardo Lerma-Lasso: Carried out the research, writing of the original draft, data analysis.
- Harold Andres Chañag-Miramag: Carried out the research, writing of the original draft, data analysis.
- Hernán Ojeda-Jurado: Research, writing the original draft.
- Diego Hernán Meneses-Buitrago: Writing the original draft, data analysis.
- Hugo Ruiz-Eraso: Did the design of the methodology, writing, revision and edition.
- Edwin Castro-Rincón: Contributed to the design of the methodology, writing, revision and edition.

Conflict of interests

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

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