Scientific Paper

Evaluation and selection of forage grass and legume species in Nariño, Colombia

Paola Andrea Portillo-López, Diego Hernán Meneses-Buitrago, Sonia Patricia Morales-Montero, Máryory Maricela Cadena-Guerrero and Edwin Castro-Rincón

Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Centro de Investigación Obonuco, Pasto, Colombia.
E-mail: pportillo@agrosavia.co
ORCID: (https://orcid.org/0000-0003-3033-3079)

Abstract

Forages are the prevailing feeding alternative within the different livestock production systems in the tropic; nevertheless, they often show limitations in quantity and quality. The objective of this study was to evaluate the productivity and quality of 18 forage species for their use in the high tropic of Nariño, Colombia. The trials were established in two localities (Pasto and Sapuyes). The design was completely randomized blocks, with 18 treatments and three repetitions: ten ryegrass cultivars, three naturalized pastures (kikuyu, Yorkshire fog and cock's foot), three legumes and two forage creeping non-legume plants (broadleaf plantain and common chicory). During the seasons of high and low rainfall, the following variables were evaluated: dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and net lactation energy (NLE). During the two periods of high and low rainfall, the ryegrasses Aubade and Italiano; the perennial cultivars Yorkshire fog, Columbia and Boxer; the legume vetch and the non-legume creeping plants common chicory and broadleaf plantain showed the best CM, CP, NDF, ADF and NLE values in the two localities. The adaptation of the different ryegrass cultivars is a characteristic that affected the quality of the produced biomass.

Keywords: herbaceous plants, production, quality

Introduction

The largest cattle milk producer per year is the United States, which produces 91,3 thousand millions liters (equivalent to 25 % of the world production), followed by India with 60,6 thousand million liters (17 %), according to FAOSTAT (2017). In Latin America and the Caribbean, Argentina occupies the first place in production with 10,4 thousand million liters, followed by such countries as Brazil and Colombia; the latter occupies the fourth position, with 6,4 thousand million liters and an average annual growth (since 2012) of 100 thousand liters. One of the reasons which have contributed to the increase of production is that the high tropic zones of Colombia have become specialized in milk production, based on the breeding of cattle and forage feedstuffs (FEDEGAN, 2017).

Forages constitute the prevailing feeding alternative in the different cattle production systems at national scale, because they constitute the most economical source to satisfy the ruminants' voluntary intake, and are necessary to guarantee their adequate rumen physiology (Reynolds, 2000). However, the high variability in the management of available forages for grazing has caused different degradation degrees in pasturelands established with kikuyu [*Cenchrus clandestinus* (Hochst. Ex Chiov.) Morrone], prevailing grass in 80 % of the specialized dairy exploitation systems of the high tropic; the dairy production basin of the Nariño department is not alien to this problem.

The adequate evaluation and selection of the forages that are adapted to each region will allow that the animal husbandry sector dedicated to specialized dairy production of the Nariño high tropic increases its productivity and profitability (Cadena, *et al.,* 2019a). In this sense, cultivated pastures could impact to a large extent the technological development of production systems, because they are the basis feedstuff of ruminants, but they are often found in limited quantity and quality (Sanchez and Villaneda, 2009).

The objective of this study was to evaluate the productivity and quality of 18 forage species of potential use in the high tropic of Nariño, Colombia.

Materials and Methods

The study was conducted in two localities of the Nariño department. A trial was established at the Obonuco Research Center of the

Colombian Corporation of Agricultural Research (AGROSAVIA), located in the Pasto municipality, at 2 905 m.a.s.l. (1°88'918" N and 77°306'083" W), on an Andisol soil of sandy loam texture; annual average temperature and rainfall were 12 ºC and 1 100 mm, respectively. The other experiment was established in the dairy farm Chimangual, located in the Sapuyes municipality, at 3 157 m.a.s.l. (1°02'655" N and 77°45'388" W), on Andisol soil of sandy loam texture; the average temperature was 9 ºC and the rainfall, 1 200 mm (UDENAR, 2016). A bimodal distribution was shown with two dry seasons (January-February) and two rainy periods (March-May and September-November). The data were obtained from the hydrometeorological station of IDEAM (Institute of Hydrology, Meteorology and Environmental Studies) –with code 52055020– located in the Túquerres municipality, Nariño Department; and from the Vantage Pro 2 automatic climate station, located in the Obonuco Research Center of AGROSAVIA.

The agronomic management was similar in both localities. Land preparation was performed with two vibratory chisel plow passes and two heavy harrow passes. The ryegrasses (50 kg ha^{-1}), cock's foot (50 kg ha^{-1}), legumes (13 kg ha^{-1}) and non-leguminous creeping plants (7 kg ha^{-1}) were sown by sexual reproduction; while Yorkshire fog and kikuyu (100 kg ha^{-1}), by vegetative reproduction (tillers and stolons, respectively). Fertilization was manually performed, in a fractionated way: at the moment of sowing and four months later with 100 kg N ha^{-1}, 75 kg P_2O_5 ha^{-1}, 30 kg K_2O ha^{-1} and 12 kg Mg ha^{-1} in each application.

Evaluated species and experimental design. The work was conducted between November, 2016, and December, 2017. Eighteen forage species were selected, taking into considerations such characteristics as: adaptation to climate and soil conditions of the high tropic, productive potential, nutritional value of reference, health performance and animal response; besides their seed availability and, in some cases, their rusticity. The evaluated plants (treatments) were:

- Ten ryegrass cultivars: five annual ones (*Lolium multiflorum* Lam): Aubade, Bianual Max, Magnum, Italiano and Bison; two hybrids (*Lolium hybridum* Hausskn): Boxer and Bestfor plus; and three perennial ones (*Lolium perenne*): Ohau, Samson and Columbia.
- Three naturalized species: kikuyu ([*Cenchrus clandestinus* (Hochst. Ex Chiov.) Morrone], Yorkshire fog (*Holcus lanatus* L.) and cock's foot (*Dactylis glomerata* L.).
- Three legumes: white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.) and vetch (*Vicia sativa* L.)
- Two non-legume creeping plants: chicory (*Cichorium intybus* L.) and broadleaf plantain (*Plantago major* L.).

A complete block randomized design was used, with three repetitions and eighteen treatments. Each experimental unit measured 12 m^2, for a total area of 1 258 m^2.

Evaluated variables. Three months after sowing (establishment period) a homogenization cut was made. Six cuts were performed, three in the rainy season (between March and June, 2017) and three in the dry season (between July and September, 2017). The evaluations had the same frequency for all the treatments. In each experimental unit sampling was carried out 35 days after cutting. The dry matter (DM) yield was evaluated based on the methodology proposed by Toledo and Schultze-Kraft (1982); as well as crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and net lactation energy (NLE). For the bromatological analysis the near infrared spectroscopy methodology –NIRS– (Ariza-Nieto *et al*., 2018) was used; they were made for each one of the cuts in each season.

Statistical analysis. The data were analyzed through the statistical software R.V.3.5.1 (R Development Core Team, 2018), with the agricultural package (Mendiburu, 2019). For each group of species variance analysis (ANOVA) was made, and Tukey's test was applied to establish the significant differences ($p \leq 0,05$). For such purpose the locality, evaluation period and studied species were taken into consideration.

Results

Pasto locality. In the rainy season, significant differences were found in the variable NDF for the annual grasses; the ryegrasses Bianual Max and Magnum reached an average of 51,68 and 51,18 %, respectively. In the perennial grasses significant differences were found in all the evaluated variables. The Yorkshire fog and ryegrasses Ohau, Boxer and Bestfor Plus stood out for their higher biomass production (2 462,4; 2 459,8; 2 396,4 and 2 305,3 kg DM/ha, respectively). Regarding CP, kikuyu (23,3 %) was higher compared with all the species, with the exception of Yorkshire fog; while in the NDF cock's foot (54,3 %) stood out, without significant differences with regards to most of the species. In ADF and NLE, the highest value was for kikuyu (table 1).

For vetch, broadleaf plantain and chicory, a DM yield of 3 894 kg/ha; 3 514,4 kg/ha and 2 074,4 kg/ha, was found, respectively. Broadleaf plantain and vetch showed higher DM yield, compared with white and red clover. The crude protein percentage had a significant variation during the rainy season.

Regarding the NDF and ADF percentage of the legumes and non-leguminous creeping plants, vetch showed the highest values (34,3 and 21,5 %, respectively), compared with broadleaf plantain and chicory. The red clover had a higher NDF percentage (38,6) than all the others. White clover (1,59 Mcal/kg DM) and red clover (1,57 Mcal/kg DM) showed a higher NLE value, compared with broadleaf plantain (1,45 Mcal/kg DM).

For the dry season, the annual and perennial grasses showed significant differences only in the variable ADF. In the annual species, the ryegrass Italiano (22,5) had the highest value and ryegrasses Bianual Max (19,9) and Aubade (20,5), the lowest ones; while among the perennial grasses, kikuyu showed the highest value and the ryegrass Bestfor Plus, the lowest (table 2).

The annual *Lolium* cultivars showed the highest DM yields in the rainy season, between 2 439,7 and 3 165,1 kg DM/ha/cut; while the perennial cultivars had between 130 and 2 462 kg DM/ha/cut (tables 1 and 2); but the yield of the annual ones was more affected by rainfall scarcity and their yield was surpassed by the perennial cultivars.

In general, during the dry season the promising species broadleaf plantain and chicory showed higher DM production than the clovers; however, their CP, NDF and NLE percentage was lower.

Table 1. Production and nutritional composition of grass and legume forage species in the rainy season, in Pasto.

Cultivar	DM, kg/ha	CP, %	NDF, %	ADF, %	NLE, Mcal/kg DM
Annual grasses					
Aubade	3 165,1	16,5	48,7^{b}	18,0	1,38
Bianual Max	2 895,7	15,1	51,2^{a}	18,9	1,35
Magnum	2 575,2	15,6	51,6^{a}	19,6	1,36
Italiano	2 560,3	16,9	49,9^{ab}	18,5	1,39
Bison	2 439,8	18,6	48,6^{b}	20,2	1,40
SE ±	NS	NS	0,8*	NS	NS
Perennial grasses					
Yorkshire fog	2 462,5^{a}	21,0^{ab}	50,2^{b}	23,5^{bc}	1,43^{ab}
Ohau	2 459,8^{a}	15,6^{c}	51,3^{ab}	18,9^{a}	1,36^{c}
Boxer	2 396,4^{a}	16,1^{c}	51,2^{ab}	18,9^{a}	1,37^{bc}
Besfor Plus	2 305,3^{a}	14,9^{c}	51,6^{ab}	17,6^{a}	1,36^{c}
Columbia	2 238,3^{ab}	17,5^{bc}	48,0^{b}	17,9^{a}	1,40^{abc}
Samson	2 039,3^{abc}	15,6^{c}	50,9^{ab}	19,7^{a}	1,36^{c}
Kikuyu	1 486,6^{bc}	23,3^{a}	49,2^{b}	25,7^{c}	1,45^{a}
Cock's foot	1 306,8^{c}	17,7^{c}	54,3^{a}	22,1^{b}	1,37^{bc}
SE ±	2,2*	1,02***	1,03*	0,47***	0,02*
Legumes and non-leguminous creeping plants					
Vetch	3 894,7^{a}	26,4^{ab}	34,5^{b}	21,5^{a}	1,54^{ab}
Broadleaf plantain	3 514,5^{ab}	17,8^{c}	30,1^{cd}	11,9^{c}	1,45^{b}
Chicory	2 074,5^{bc}	22,3^{bc}	28,5^{d}	15,3^{b}	1,51^{ab}
Red clover	1 275,3^{c}	25,6^{a}	38,6^{a}	21,9^{a}	1,57^{a}
White clover	966,6^{c}	27,7^{a}	33,3^{bc}	17,3^{b}	1,59^{a}
SE ±	2,57**	0,86***	0,71***	0,76***	0,02**

NS: Not significant: * p< 0,05; **p < 0,01; ***p < 0,001.
a, b, c: means with different letters within the same column differ among them, according to Tukey's test ($p \leq 0,05$).

Table 2. Production and nutritional composition of the species in the dry season.

Cultivar	DM, kg/ha	CP, %	NDF, %	ADF, %	NLE, Mcal/kg DM
Annual grasses					
Aubade	1 050,7	15,9	51,3	20,6^{a}	1,36
Magnum	957,9	17,9	50,6	21,2^{ab}	1,39
Italiano	832,0	16,9	52,9	22,6^{b}	1,36
Bianual Max	756,8	16,3	50,2	20,0^{a}	1,36
Bison	631,0	14,0	53,0	21,5^{ab}	1,32
SE ±	NS	NS	NS	0,31**	NS
Perennial grasses					
Yorkshire fog	1 178,3	18,8	53,2	24,8^{de}	1,37
Columbia	1 081,1	13,3	54,7	20,5^{b}	1,31
Boxer	1 072,9	15,8	52,8	21,8^{bc}	1,34
Besfor Plus	987,0	13,7	51,6	20,0^{a}	1,32
Ohau	919,0	15,4	53,1	22,4^{bcd}	1,34
Kikuyu	893,7	16,1	57,6	32,5^{e}	1,27
Samson	637,0	13,5	55,2	22,9^{bcde}	1,30
Cock's foot	635,5	19,0	54,2	24,3^{cde}	1,38
SE ±	NS	NS	NS	0,53***	NS
Legumes and non-leguminous creeping plants					
Broadleaf plantain	1 612,4^{a}	18,7^{b}	30,1^{b}	12,3^{a}	1,46^{b}
Chicory	1 511,7^{ab}	17,5^{b}	30,1^{b}	13,3^{ab}	1,44^{b}
Red clover	582,4^{bc}	28,2^{a}	38,2^{a}	20,8^{c}	1,58^{a}
White clover	318,3^{c}	25,5^{a}	35,0^{ab}	17,7^{bc}	1,55^{a}
SE ±	0,207**	0,66***	1,61*	0,93**	0,01***

NS: Not signficant: * p< 0,05; **p < 0,01; ***p < 0,001.
a,b,c: means with different letters within the same column differ among them, according to Tukey's test ($p \leq 0,05$).

The CP percentage during this season was higher for red and the white clover, and they differed significantly from broadleaf plantain and chicory.

The NDF percentage of red clover was significantly different from that of broadleaf plantain and chicory. The lowest ADF was shown by broadleaf plantain. Red clover and white clover had a higher NLE percentage, compared with broadleaf plantain and chicory.

Sapuyes locality. In the rainy season significant differences were observed among the annual grasses in the variables CP, NDF and ADF; the CP percentage of ryegrass Italiano was the best. Regarding NDF, the highest percentage value was found in ryegrasses Bianual Max and Magnum; while in the ryegrass Bison the ADF was lower.

In the case of the perennial grasses, differences were found in all the variables; ryegrass Columbia was the one with higher DM yield, and the one with the lowest yield was kikuyu. The CP percentage of ryegrass Boxer was higher than the other perennial grasses. The highest percentage value of NDF was observed in kikuyu; and regarding ADF, ryegrass Columbia showed the lowest value and kikuyu, the highest. The NLE varied between 1,42 and 1,50 Mcal/kg DM for most of the perennial grasses, with the exception of kikuyu (table 3).

In the rainy season there were no significant differences in the DM yield; but there were in the CP. White clover stood out with the highest percentage value (32,3), compared with red clover (28,2), chicory (24,8) and broadleaf plantain (18,6).

There were no significant differences in the NDF either. However, the ADF showed the lowest percentage value in chicory, which differed significantly from the red clover.

Table 3. Production and nutritional composition of the grass and legume species in the rainy season, in Sapuyes.

Cultivar	DM, kg/ha	CP, %	NDF, %	ADF, %	NLE, Mcal/kg DM
Annual grasses					
Italiano	2 372,7	23,9^{a}	43,3^{c}	22,7^{bc}	1,48
Aubade	2 170,6	23,0^{ab}	44,6^{bc}	22,0^{abc}	1,47
Magnum	1 708,0	20,3^{bc}	48,1^{a}	21,6^{ab}	1,42
Bianual Max	1 095,2	21,7^{abc}	48,4^{a}	23,4^{c}	1,44
Bison	788,2	19,2^{c}	46,2^{ab}	21,3^{a}	1,41
SE ±	NS	0,79*	0,74**	0,43*	NS
Perennial grasses					
Columbia	3 735,5^{a}	24,5^{ab}	43,5^{e}	22,8^{a}	1,50^{a}
Boxer	2 985,1^{ab}	25,0^{a}	44,8^{de}	23,1^{ab}	1,50^{a}
Besfor Plus	2 852,3^{ab}	22,3^{ab}	47,3^{bc}	24,2^{b}	1,44^{a}
Ohau	1 538,1^{ab}	21,5^{ab}	45,2^{cde}	23,2^{ab}	1,44^{a}
Yorkshire fog	1 506,8^{ab}	21,7^{ab}	48,8^{b}	26,1^{c}	1,42^{ab}
Samson	1 026,5^{ab}	21,8^{ab}	46,8^{bcd}	24,3^{b}	1,44^{a}
Kikuyu	568,8^{b}	18,7^{b}	52,8^{a}	31,3^{d}	1,33^{b}
SE ±	0,283*	1,16*	0,46***	0,25***	0,02**
Legumes and non-leguminous creeping plants					
Chicory	5 409,2	24,8^{c}	33,8	16,4^{a}	1,54^{b}
Broadleaf plantain	2 996,0	18,6^{d}	33,5	16,9^{ab}	1,43^{c}
White clover	2 470,1	32,3^{a}	36,1	20,3^{bc}	1,65^{a}
Red clover	2 369,6	28,2^{b}	37,2	21,6^{c}	1,57^{b}
SE ±	NS	0,58***	NS	0,72**	0,01***

NS: Not significant: * p< 0,05; **p < 0,01; ***p < 0,001.
a,b,c: means with different letters within the same column differ between them, according to Tukey's test ($p \leq 0,05$).

The NLE did not differ between red clover and chicory, but it did differ between broadleaf plantain and white clover; the latter had the highest percentage.

No significant differences were found for the annual grasses; nevertheless, the genotypes of higher DM yield were Italiano and Bianual Max. In the perennial grasses differences were found in the variables DM and ADF; ryegrass Columbia stood out with the highest DM yield and the lowest ADF value (table 4).

In the dry season there were significant differences in DM. Vetch showed the highest value, followed by chicory and broadleaf plantain, and the lowest yields were obtained in white clover and red clover. The CP of white and red clover was significantly different from that of broadleaf plantain. Likewise, the NLE in white clover and in red clover differed significantly from broadleaf plantain and vetch.

Discussion

The agroclimatic conditions influenced forage establishment and production, and differential responses occurred in some variables in each evaluation period. In the Pasto and Sapuyes localities the grass (annual and perennial) species showed a similar response pattern; the highest dry matter yields were obtained during the rainy season, which decreased in the dry season. Similar results were reported by Méndez *et al*. (2014), Zambrano *et al*. (2014) and Vargas-Martínez *et al*. (2018); which corroborates that in the dry seasons there is higher forage offer and higher dry matter yields.

Among the grasses, in the Pasto locality a good performance of Yorkshire fog and the ryegrasses was shown in the two seasons; these results are higher than the ones reported by Martínez (2008), who found productions in Yorkshire fog of 8 000 kg DM/ha/year. In

Table 4. Production and nutritional composition of the grass and legume species in the dry season, in Sapuyes.

Cultivar	DM, kg/ha	CP, %	NDF, %	ADF, %	NLE, Mcal/kg DM
Annual grasses					
Italiano	1 938,4	17,8	48,9	21,0	1,39
Bianual Max	1 252,5	13,8	48,6	18,9	1,33
Aubade	1 057,6	16,1	43,2	15,1	1,39
Magnum	937,7	12,6	45,4	17,4	1,32
Bison	707,2	11,9	50,1	17,8	1,30
SE ±	NS	NS	NS	NS	NS
Perennial grasses					
Columbia	1 883,7^{a}	14,9	44,4	15,7^{a}	1,37
Yorkshire fog	506,6^{ab}	13,6	51,8	22,9^{bc}	1,30
Besfor Plus	468,4^{b}	12,3	47,4	17,5^{ab}	1,31
Kikuyu	462,7^{b}	18,9	52,5	24,0^{c}	1,38
Ohau	461,5^{b}	16,6	45,4	17,6^{ab}	1,39
Cock's foot	421,5^{b}	17,6	49,9	20,3^{abc}	1,39
Boxer	382,6^{b}	13,9	47,0	17,4^{ab}	1,34
Samson	271,4^{b}	17,3	47,2	18,4^{abc}	1,39
SE ±	0,408*	NS	NS	1,38**	NS
Legumes and non-leguminous creeping plants					
Vetch	1 206,4^{a}	16,0^{ab}	33,6	19,7	1,3^{b}
Chicory	441,6^{ab}	16,4^{ab}	33,6	13,6	1,4^{ab}
Broadleaf plantain	325,9^{b}	11,6^{b}	32,7	10,8	1,3^{b}
White clover	310,2^{b}	23,8^{a}	36,7	16,9	1,5^{a}
Red clover	296,2^{b}	23,3^{a}	37,7	18,8	1,5^{a}
SE ±	0,207*	1,72**	NS	NS	0,04*

NS: Not significant: * p< 0,05; **p < 0,01; ***p < 0,001.
a,b,c: means with different letters within the same column differ among them, according to Tukey's test ($p \leq 0,05$).

addition, this author emphasized that Yorkshire fog shows good forage production potential, acceptable nutritional value and moderate tolerance to intense and frequent defoliation; which allows to classify it as an exceptional grass for its incorporation to extensive breeding, because it generates an important forage production in a large diversity of soils.

Regarding the ryegrass cultivars, when they were evaluated in the rainy season similar yields were obtained to the ones reported in a study about the adaptation of ryegrass cultivars in the high Nariño tropic (Cadena *et al*., 2019b), with more than 2 000 kg DM/ha/cut.

The protein content of the grasses was higher in the rainy season in the two localities; while in the dry season it decreased remarkably.

The nitrogen fertilization in the rainy seasons favors growth, development and, thus, CP content (Andrade, 2006). Likewise, Gómez-Insuasti *et al*. (2014) stated that the cutting age has direct relation with the chemical composition of pasture. In the Pasto zone, kikuyu was one of the grasses with higher protein content, which can be ascribed to the fact that its growth habit favored the leaf: stem ratio. This prevents the chemical composition of the pasture from changing so markedly, as with other forage grasses.

The NDF contents of kikuyu and cock's foot were lower than the ones reported by Cuesta *et al*. (2006): 58 and 59 %, respectively. The ryegrasses showed a lower NDF content with regards to kikuyu, which allows to have a higher content of intracellular components (Villalobos and Sánchez,

2010). The quality and quantity of the consumed fiber affect the voluntary intake capacity, that is, when the forage fiber concentration increases, intake and energy concentration decrease (Weiss, 1993).

The ADF values of the ryegrass cultivars, annual as well as perennial, were low and similar to the ones reported by Flores *et al.* (2013). This is shown in a high content of hemicellulose, higher solubility carbohydrate and easily utilizable energy source (Zambrano *et al*., 2014); which was due to the cutting age, soil fertility and uniform rainfall distribution, mainly. Kikuyu, Yorkshire fog and cock's foot showed the highest values in the two localities and seasons, which is a disadvantage of these grasses, as high ADF concentrations are associated with low rumen digestibility (Van-Soest *et al*., 2000; Apáez *et al*., 2012); because, being a constituent of the cell wall, lignin digestibility is practically null.

In the Sapuyes locality kikuyu showed the lowest value, compared with that of the other perennial grasses, which could have been due to the differences in the agroclimatic conditions of each locality. Correa *et al.* (2008), when evaluating the nutritional value of kikuyu, reported 1,15 Mcal of NLE/kg DM, lower value than the one found in this research. Silva *et al*. (2015) also found a similar response to that of this study during the rainy season, in an energy evaluation of kikuyu and a perennial ryegrass cultivar.

Larbi *et al.* (2010) reported a forage yield for *V. sativa* of 3 309 kg DM in the rainy season (average of 283 mm), which coincides with the rainy period of this study (average of 232 mm), and the highest green forage production was obtained in the cv. Vicia (3 894,67 kg DM/ha). These authors stated that the variations in DM yield could be related to the rainfall quantity and distribution and their effect on the growth and efficiency with which the cultivars turned the intercepted photosynthetically active radiation into biomass.

In the Pasto locality, during the dry season, broadleaf plantain and chicory had higher DM yield than the clovers.

Li and Kemp (2005) referred that in the summer these two species produce more DM and show better nutritional qualities than perennial forages; in this regard, in literature it is stated that broadleaf plantain can produce well during the summer, because it has certain tolerance to drought and heat (Labreveux *et al*., 2004).

Charl Li and Kemp (2005) indicated that chicory has a deeper and thicker root than broadleaf plantain, for which it is highly productive under the dry conditions of summer; likewise, it often tolerates humidity stress (Nie *et al.,* 2008).

In this sense, Li and Kemp (2005) reported that in the first year of evaluation broadleaf plantain produced 1 416 kg DM/ha, lower value than the one found in this study, possibly due to the fact that it was planted in autumn, when rainfall was low because the summer was just over; this could have also been due to the grazing pressure, which decreased plant survival. In this study the plants were sown in the second bimester of the year, rainy season in the zone (90,4 mm), and the harvest was carried out mechanically.

In a trial conducted by Springer and Aiken (2015)theoretical ethanol yield, crude protein (CP during four years, with different harvest times for white clover, the highest CP percentage (24 ± 3 %) was obtained in the second year, in which a total rainfall of 405 mm was reported. This coincides with the value of this study (370 mm), in which white clover showed the highest CP content (27,7 %). In this regard, these authors stated that under drier conditions the plants can tend to reallocate nutrients to the roots, reducing the nutritional value of the forage.

In an experiment made by Koukolová *et al.* (2010) in the months from May to August, with 324 mm of rainfall, the nutritional value of red clover was evaluated during different phenological stages, and 39,5 % of NDF was obtained in the phase of young sprouts with formation of floral buds. Similar results were found in this study, with 370 mm of rainfall, in which the cuts for the cultivar red clover coincided with the phenological stage of floral bud and 38,6 % of NDF was reached. The nutritional value of forages is controlled, to a large extent, by light, temperature, humidity and maturity factors, although the response depends on each species (Van-Soest, 1969).

The nutritional status of broadleaf plantain is not well established, because most of the studies carried out have been focused on its medicinal characteristics (Sanderson *et al.,* 2003). However, Box *et al.* (2016) found values for CP, ADF and NDF of 22,3; 22,4 and 29,9 %, respectively; the CP and ADF values were higher than the ones in this study, as a result of fertilization with 70 kg/ha and irrigation.

Regarding the variables CP, NDF, ADF and NLE, red clover showed the best results compared

with the other species. In this regard, Vargas-Martínez *et al.* (2018) evaluated two red clover varieties in the high Colombian tropic and found similar values of CP (22,8 %), NDF (36,4 %), ADF (16,7 %) and NLE (1,60 %) to the ones in this study, which could have been likely due to the physical conditions of the soils and their preparation.

For the Sapuyes locality, perennial ryegrass Columbia maintained the highest yields in the rainy and dry seasons, which proved its good productive potential compared with the other perennial grasses and with other studied cultivars. Thus, Vargas-Martínez *et al.* (2018) reported 2 520 kg DM/ha/cut. However, in other studies with perennial ryegrass (*L. perenne*), Velasco-Zebadúa *et al.* (2007) and Villalobos and Sánchez (2010) obtained higher yields than those in this research.

In the Sapuyes locality, during the rainy season, among the annual grasses the one with the best performance was ryegrass Italiano (23,8 %); while among the perennial ones, ryegrass Boxer was the best (25,0). These results are similar to the ones obtained by Vargas-Martínez *et al.* (2018) and higher than those reported by Cuesta *et al.* (2006) in evaluations with ryegrass cultivars in the Colombian high tropic, where values lower than 15 % were obtained in the annual as well as the perennial ryegrasses.

Within the group of legumes and non-leguminous creeping plants, the best yield was that of chicory. In this regard, Matthews *et al.* (1990) evaluated the growth rate of chicory and found productions of 5 250 kg DM/ha, higher than those of traditional ryegrass and white clover. Terrill *et al.* (1992) stated that this herbaceous plant shows a variable protein content (15-26 %), similar result to that in this study and which coincides with the report by DLF Estero (2018).

Chicory is an herbaceous plant of erect growth, with pivoting root, of biannual to perennial cycle depending on the varieties. It produces well in the winter as well as in summer; its pivoting and deep root provides it with excellent drought resistance, which allows it to make good contributions in the summer. It regrows well after grazing; and, if well managed, it produces good quality forage.

The best results in CP, NDF and ADF were found for the white clover. Ayres *et al.* (1998) evaluated the effect of phenological maturity on the nutritional value of white clover during one year, and found higher percentages of CP (20), NDF (43,9) and ADF (32,3) for the rainy season (90,66 mm) than the ones in this study. This was possibly due to the fact that in the evaluated season the species was in the stage of mature seed, and in this study, in early flowering stage. These authors stated that white clover, as in other pasture species, undergoes substantial changes in the nutritional value, along with the phenological development during the growth phase.

In a study with *V. sativa* (Larbi *et al.,* 2010) a yield of 2 396 kg DM/ha was found during the dry season, with an average of 140 mm; that is, 50 mm more than in equal season in this study, in which the highest DM production was observed in vetch. The differences in yield among the species in this study for the dry season suggest that they could be selected for each season, taking into consideration their yield and quality. Based on this, vetch has potential for good quality DM production in the rainy or the dry season. These authors stated that the species yield varies under dry conditions, and could be used as a selection characteristic for the production of quality forage.

Vargas *et al.* (2014), when making a nutritional evaluation in two cutting periods (35 and 45 days) for mixtures of grasses and legumes of the Colombian high tropic, found 31,2 % of CP; 30,8 % of NDF and 15,9 % of ADF for white clover. When comparing these values with the ones of this study, the protein percentage was higher; while NDF and ADF were similar, possibly due to the edaphoclimatic conditions of the zone where the experiment was conducted. FAO (2013) stated that pastures, just like the crops that are planted for obtaining food, fiber and energy, require specific conditions to develop, such as an optimum degree of temperature and a quantity of sufficient water. To a certain extent, warmer climates can benefit forage growth in some parts of the world; however, if the recommended levels for these plants are exceeded or if there is no water or sufficient nutrients, a yield decrease will probably occur.

Conclusions

The adaptation of the different ryegrass cultivars is a characteristic that affected the quality of the produced biomass.

The annual and perennial cultivars Columbia and Boxer represent a good choice for specialized dairy animal husbandry systems of the high Nariño tropic. On the other hand, kikuyu and Yorkshire fog stood out as the best naturalized species because

of their yield and quality; while broadleaf plantain, due to its quality, can be implemented in the pasturelands after it is evaluated commercially.

Acknowledgements

The authors thank the Colombian Agricultural Research Corporation (AGROSAVIA), the Society of Agriculturalists and Ranchers of Nariño (SAGAN) and the University of Nariño, for having allowed the development of this research.

Bibliographic references

Andrade, M. *Evaluación de técnicas de manejo para mejorar la utilización del pasto kikuyo (Pennisetum clandestinum Hochst. ex Chiov) en la producción de ganado lechero en Costa Rica*. Tesis de Licenciatura en Zootecnia. San José: Facultad de Ciencias Agroalimentarias, Escuela de Zootecnia, Universidad de Costa Rica, 2006.

Apáez-Barrios, P.; Escalante-Estrada, J. A. S.; Sosa-Montes, E.; Apáez-Barrios, Maricela; Rodríguez-González, María T. & Raya-Montaño, Yurixhi A. Producción y calidad nutrimental de vaina del frijol chino, *Vigna unguiculata* (L.) Walp, en función de arreglo topológico y tipo de fertilización. *Rev. FCA UNCUYO*. 48 (2):31-42, 2016.

Ariza-Nieto, C.; Mayorga, O. L.; Mojica, B.; Parra, D. & Afanador-Tellez, G. Use of LOCAL algorithm with near infrared spectroscopy in forage resources for grazing systems in Colombia. *J. Near Infrared Spectrosc*. 26 (1):44-52, 2018. DOI: http://doi.org/10.1177/0967033517746900.

Ayres, J. F.; Nandra, K. S. & Turner, A. D. A study of the nutritive value of white clover (*Trifolium repens* L.) in relation to different stages of phenological maturity in the primary growth phase in spring *Grass For. Sci*. 53 (3):250-259, 1998. DOI: https://doi.org/10.1046/j.1365-2494.1998.00137.x.

Box, L.; Edwards, G. & Bryant, R. H. Milk production and urinary nitrogen excretion of dairy cows grazing perennial ryegrass-white clover and pure plantain pastures. *Proc. New Zeal. Soc. An*. 76:18-21, 2016. DOI: http://doi.org/10.1080/00288233.2017.1366924.

Cadena, M. M.; García, M. A. & Castro, E. Estabilidad fenotípica de genotipos de *Lolium* sp. en el trópico alto de Nariño, Colombia. *Agron. Mesoam*. 30 (2):483-495, 2019a. DOI: https://doi.org/10.15517/am.v30i2.34307.

Cadena, M. M.; García, M. A.; Meneses, D. H.; Morales, S. P. & Castro, E. Adaptación de diez cultivares de *Lolium* sp. en el trópico alto de Nariño, Colombia. *Agron. Mesoam*. 30 (1):165-178, 2019b. DOI: https://doi.org/10.15517/am.v30i1.34094.

Correa, H. J.; Carulla, J. E. & Pabón, Martha L. Valor nutricional del pasto kikuyo (*Pennisetum clandestinum* Hoechst Ex Chiov.) para la producción de leche en Colombia (Una revisión). *LRRD*. 20 (4):59. http://www.lrrd.org/lrrd20/4/corra20059.htm, 2008.

Cuesta, P. A.; Bolaños, A. M. & Betancourth, C. A. *Nuevas especies forrajeras para mejorar la competitividad de los sistemas de producción de leche del altiplano de Nariño*. Colombia: CORPOICA, 2006.

DLF Estero. *Forrajeras*. Montevideo: DLF Estero S.A. https://estero.com.uy/catalogos/CATALOGO_FORRAJERAS_DLF_ESTERO_2018.pdf, 2018.

FAO. *El sector lechero mundial : Datos*. Roma: FAO. http://www.dairydeclaration.org/Portals/153/FAO-Global-Facts-SPANISH-F.PDF?v=1, 2013.

FAOSTAT. Ganadería primaria. Roma: FAO; 2017.

FEDEGAN. *Estadísticas: Producción*. Bogotá: Federación Colombiana de Ganaderos. https://www.fedegan.org.co/estadisticas/produccion-0, 2017.

Flores, G.; Díaz, N.; Díaz, D.; Valladares, J.; Pereira-Crespo, S.; Fernández-Lorenzo, B. *et al.* Evaluación de cultivares de raigrás italiano e híbrido como cultivo de invierno para ensilar en primavera. *Pastos*. 43 (1):20-34, 2013.

Gómez-Insuasti, A. S.; Silva-Parra, Amanda; Salazar, J. J. & Andrade-García, J. Producción de materia seca y calidad del pasto kikuyo *P. clandestinum* en diferentes niveles de fertilización nitrogenada y en asocio con aliso *Alnus acuminata* en el trópico alto colombiano. *Anais do 1 Simpósio Internacional de Arborização de Pastagens em Regiões Subtropicais*. Colombo, Brasil: Embrapa Florestas. p. 32-41, 2014.

Koukolová, V.; Homolka, P.; Koukol, O. & Jančík, F. Nutritive value of *Trifolium pratense* L. for ruminants estimated from *in situ* ruminal degradation of neutral detergent fibre and *in vivo* digestibility of organic matter and energy. *Czech J. Anim. Sci*. 55 (9):372-381, 2010. DOI: http://doi.org/10.17221/304/2009-CJAS.

Labreveux, María; Hall, M. H. & Sanderson, M. A. Productivity of chicory and plantain cultivars under grazing. *Agron. J.* 96 (3):710-716, 2004. DOI: http://doi.org/10.2134/agronj2004.0710.

Larbi, A.; Hassan, S.; Kattash, G.; Abd El-Moneim, A. M.; Jammal, B.; Nabil, H. *et al.* Annual feed legume yield and quality in dryland environments in north-west Syria: 1. Herbage yield and quality. *Anim. Feed Sci. Technol*. 160 (3-4):81-89, 2010. DOI: http://doi.org/10.1016/j.anifeedsci.2010.07.003.

Li, G. & Kemp, P. D. Forage chicory (*Cichorium intybus* L.): A review of Its agronomy and animal production. *Adv. Agron*. 88 (5):187-222, 2005. DOI: https://doi.org/10.1016/S0065-2113(05)88005-8.

Martínez, M. *Holcus lanatus*. *Plan Agropecuario*. Uruguay. https://www.planagropecuario.org.uy/publicaciones/revista/R125/R_125_48.pdf, 2008.

Matthews, P. N. P.; Kemp, P. D. & Austin, G. M. T. The effect of grazing management on the growth and reproductive development of chicory. *Proc. Agron. Soc. N. Z*. 20:41-43, 1990.

Méndez, D. G.; Frigerio, K.; Costa, M.; Mattera, J.; Romero, N.; Fontana, L. *et al.* Producción estacional de forraje de cultivares de *Lolium multiflorum* Lam. en diferentes localidades. En: *Memoria Técnica 2013-2014*. Argentina: INTA, 2014.

Mendiburu, F. de. *Package 'agricolae'. Statistical Procedures for Agricultural Research*. Version 1.3-1. Vienna: The R Project. https://cran.r-project.org/web/packages/agricolae/agricolae.pdf, 2019.

Nie, Z. N.; Miller, S.; Moore, G. A.; Hackney, B. F.; Boschma, S. P.; Reed, K. F. M. *et al.* Field evaluation of perennial grasses and herbs in southern Australia. 2. Persistence, root characteristics and summer activity. *Aust. J. Exp. Agric*. 48:424-435, 2008. DOI: http://doi.org/10.1071/EA07136.

Powell, A. M.; Kemp, P. D.; Jaya, I. K. D. & Osborne, M. A. Establishment, growth and development of plantain and chicory under grazing. *Proc. N. Z. Grassl. Assoc*. 69:41-45, 2007.

Reynolds, C. Forage evaluation using measurements of energy metabolism. In: D. I. Givens, E. Owen, R. F. E. Axford and H. M. Omed, eds. *Forage evaluation ruminant nutrition*. USA: CABI Publishing. p. 95-111, 2000.

Sánchez, L. & Villaneda, E. *Renovación de praderas en sistemas de producción de leche especializada en el trópico altop colombiano*. Colombia: CORPOICA, 2009.

Sanderson, M. A.; Labreveux, Maria; Hall, M. H. & Elwinger, G. F. Nutritive value of chicory and English plantain forage. *Crop Sci*. 43:1797-1804, 2003. DOI: http://doi.org/10.2135/cropsci2003,1797.

Silva, L.; Guevara, P. & Pazmiño, J. Evaluación energética de *Pennisetum clandestinus* y *Lolium perenne* en diferentes edades de corte para alimentación de bovinos. *Maskana*. 6 (ne):199-200, 2015.

Springer, T. L. S. & Aiken, G. E. Harvest frequency effects on white clover forage biomass, quality, and theoretical ethanol yield. *Biomass Bioenerg*. 78:1-5, 2015. DOI: http://doi.org/10.1016/j.biombioe.2015.04.003.

Terrill, T. H.; Rowan, A. M.; Douglas, G. B. & Barry, T. N. Determination of extractable and bound condensed tannin concentrations in forage plants, protein concentrate meals and cereal grains. *J. Sci. Food Agric*. 58:321-329, 1992. DOI: https://doi.org/10.1002/jsfa.2740580306.

Toledo, J. M. & Schultze-Kraft, R. Metodología para la evaluación agronómica de pastos tropicales. En: J. M. Toledo, ed. *Manual para la evaluación agronómica*. Cali, Colombia: CIAT, RIEPT, 1982.

UDENAR. *Granja Lechera Chimangual*. Nariño, Colombia: Universidad de Nariño. http://www.udenar.edu.co/project/granja-lechera-chimangual/, 2016.

Van Soest, P. J.; Van Amburgh, M. E. & Tedeschi, L. O. *Rumen balance and rates of fiber digestion*. New York: Cornell University, 2000.

Van-Soest, P. J. Composition, maturity, and the nutritive value for forages. In: G. J. Hajny and E. T. Reese, eds. *Cellulases and their applications*. vol. 95. Washington, USA: American Chemical Society. p. 262-278, 1969.

Vargas, J.; Pabón, M. & Carulla, J. Producción de metano *in vitro* en mezcla de gramineas-leguminosas del tropico alto colombiano. *Arch. Zootec*. 63 (243):397-407, 2014. DOI: http://doi.org/10.4321/S0004-05922014000300001.

Vargas-Martínez, J.; Sierra-Alarcón, Andrea; Benavidez-Cruz, J.; Avellaneda-Avellaneda, Y.; Mayorga-Mogollón, Olga & Ariza-Nieto, Claudia. Establecimiento y producción de raigrás y tréboles en dos regiones del trópico alto colombiano. *Agron. Mesoam*. 29 (1):177-191, 2018. DOI: http://doi.org/10.15517/ma.v29i1.28077.

Velasco-Zebadúa, María E.; Hernández-Garay, A. & González-Hernández, V. A. Cambios en componentes del rendimiento de una pradera de ballico perenne, en respuesta a la frecuencia de corte. *Rev. Fitotec. Mex*. 30 (1):79-87, 2007.

Villalobos, L. & Sánchez, J. M. Evaluación agronómica y nutricional del pasto ryegrass perenne tetraploide (*Lolium perenne*) producido en lecherías de las zonas altas de Costa Rica. II. Valor nutricional. *Agron. Costarricense*. 34 (1):43-52, 2010.

Weiss, W. P. *Fiber requirements of dairy cattle: Emphasis NDF*. Ohio, USA: Department of Dairy Science, 1993.

Zambrano, Gema; Apráez, J. E. & Navia, J. F. Relación de las propiedades del suelo con variables bromatológicas de pastos, en un sistema lechero de Nariño. *Rev. Cienc. Agr*. 31 (2):106-121, 2014. DOI: http://doi.org/10.22267/rcia.143102.35.

Received: June 11, 2019
Accepted: August 28, 2019