Scientific Paper

Adaptation of grasses associated with *Lotus uliginosus* Schkuhr in the high Colombian tropic

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Abstract

The objective of this study was to evaluate the agronomic performance of 11 grass accessions associated with the legume *Lotus uliginosus Schkuhr*, at two cutting ages, in the high Andean tropic of Colombia. The trial was conducted at the Marengo Animal Husbandry Center, of the National University of Colombia, in the Mosquera municipality, Cundinamarca, Colombia. Eleven grass accessions associated with the legume and a pure control *(Cenchrus clandestinus* Hochst. ex Chiov), were evaluated, using a randomized block design with split-strip arrangement and three repetitions. The biomass production was measured when cutting at 45 and 70 days in the rainy and dry seasons. In general, *L. uliginosus* as well as the associated grasses showed good growth in the establishment stage. The total aerial biomass production was higher in the rainy season and with the 70-day frequency, especially in the associations with *Festuca rubra, Festuca arundinacea, Bromus catharticus, Anthoxantum odoratum* and *Holcus lanatus*. The grasses *F. rubra, F. arundinacea, B. catharticus* and *C. clandestinus* (naturalized) stood out for their high aerial biomass production, with a higher production than that of the pure control. It is concluded that the associations with the best performance were *F. arundinacea* and *C. clandestinus*, the naturalized as well as the introduced one, which stood out for their higher resistance to pests and diseases during the establishment stage, showing the potential of this type of system in the high Colombian Andean tropic.

Keywords: biomass, plant establishment, forage legumes

Introduction

The agroecological zone of the high Colombian Andean tropic, whose particular microclimate characteristics favor specialized milk production, dedicates 300 000 hectares to pasture production, formed in 80 % by kikuyu (*Cenchrus clandestinus* Hochst. ex Chiov), and in lower proportion ryegrass (*Lolium* sp.), oat (*Avena sativa* L.), cock's foot (*Dactylis glomerata* L.), Yorkshire fog (*Holcus lanatus* L.), clovers (*Trifolium* spp. L.) and alfalfa (*Medicago sativa* L.) (Cardenas, 2003; Sánchez and Villaneda, 2009).

With the above-mentioned materials studies have been conducted in which new forages (native and introduced) have been evaluated, in order to maintain high good-quality biomass productions throughout the year at minimum costs, searching for species with low fertilization requirements, high resistance to pests and diseases, adaptation, persistence and palatability (Ochoa *et al*., 2016).

In Colombia different pastures have been evaluated such as ryegrass (*Lolium* sp.), clovers, cock's foot and kikuyus, and a large variety of materials adapted to the conditions of the high Colombian tropic has been reported (Cadena *et al*., 2019).

Among the evaluated foreign materials *Lotus uliginosus* Schkuhr stands out, promising legume for its establishment in dairy systems in the high Colombian Andean tropic; thus, it has been proposed in several evaluation studies, in associations with grasses (Castro *et al*., 2009; Santacoloma-Varón *et al*., 2017).

In this sense, Morales *et al*. (2013) found good performance in the milk quality and production in cows that grazed in an association of *F. arundinacea* and *L. uliginosus* under conditions of the high Colombian tropic, when comparing it with pure *C. clandestinus* pastures.There are no abundant records of evaluated and released materials for the country in the case of associations of grasses and legumes.

The objective of this research was to evaluate the agronomic performance of 11 grass accessions associated with the legume *Lotus uliginosus*, at two cutting ages, in the high Colombian Andean tropic.

Materials and Methods

The trial was conducted at the Marengo Animal Husbandry Center, located on the San José lane, Mosquera municipality, Cundinamarca, Colombia.

The municipality is located at 4º 42' North latitude and 74º 12' West longitude, at an altitude of 2 650 m.a.s.l. The average temperature is 13 ºC, with fluctuations between 0 and 20 ºC, and presence of frost in January, February and early August. The mean annual rainfall is 528,9 mm. The months with average rainfall equal to or higher than 50 mm were considered as the rainy season, that is, April-May and October-November; while in the dry season the months in which at least 50 mm as average did not occur were included, and it was in correspondence with January, February and June.

The soils belong to the Tibaitatá series, which have been formed from heterogeneous materials with variable influence from volcanic ashes. They show little evolution, are generally deep, vary from well-drained to poor-drainage ones and have moderate fertility. Their texture is clay loam, pH is 4,9 and organic matter, 6,8 % (Orduz, 2014).

Treatments and experimental design. Eleven grass accessions associated with *L. uliginosus* and a pure control (*Cenchrus clandestinus)* were evaluated. The accessions were selected from the Plant Genetic Resource Unit (PGRU) of the National University. The evaluated accessions were: *Bromus catharticus* (Vahl) var. Banco, *Festuca arundinacea* (Schreb.) var. Festorina, *Dactylis glomerata* (L.) var. Knaulgrass, *Festuca pratense* (Huds) var. Preval, *Holcus lanatus* (L.) (naturalized), *Anthoxantum odoratum (*naturalized*), Cenchrus clandestinus* (pure control, naturalized), *Phleum pratense, Cenchrus clandestinus* 1 (naturalized), *Cenchrus clandestinus* 2, (introduced), *Dactylis glomerata*, var. Varaula, all of them associated with *Lotus uliginosus* (legume to be associated). A randomized block design was used with split-strip arrangement, where the experimental unit was each plot that contained each accession. The main plot was the accession and the strip, the cutting frequency (45 and 70 days). The trial had a total of 12 plots, each one with three repetitions.

Land preparation. It was prepared with one month of anticipation, using rotovator once, chisel plow twice and light harrow twice; at the same time the soil acidity was corrected with 2 000 kg of lime/ha. The total area of the experiment was 950 m^2, with plots of 2,5 by 5 meters with 1 meter distance between plots, where 5 rows of grass and two alternate rows of legume were planted through seedlings from greenhouse.

Post-establishment stage. One hundred eighty days after sowing the plots, a homogenization cut was made with scythe at 10 cm from the soil, simulating grazing. From this moment the post-establishment stage was considered as started, in which cuttings were performed every 45 and 70 days, according to the recommendations made for the species by Correa *et al*. (2016) and Vargas-Martínez *et al.* (2018).

Fertilization. The fertilization recommended for the establishment of pastures, according to the report by Bernal-Eusse (1994) and Silva (1986), was used. N was applied (50 kg/ha; applied only to the pure control) upon establishment, K (25 kg/ha), P (30 kg/ha) and Mg (25 kg/ha). The control was fertilized after each production cutting with 50 kg N/ha.

Measured variables

During the establishment. The period comprised between transplant and the following 180 days was considered as establishment, in which the following variables were measured every eight days:

- Vigor: In scale from 1 to 5, which was considered as the degree of adaptation to the environment (1: very low, 2: low, 3: regular, 4: good, 5: excellent).
- Legume cover (%): Area covered by the plant in a 1-m^2 frame.
- Grass height (from the soil to the petiole of the tallest leaf) and radius of the legume (cm; from the center to the distal end).
- Pests and diseases: In scale from 0 to 5; 0: without affectations and 5: severely affected.
- Phenology (grasses): Beginning of flowering: when 30 % of the plot showed inflorescence, it was determined that the grass started flowering. Beginning of the maturation stage: when 30 % of the plot showed mature seed.

Forage production (kg DM/ha). The forage production was measured in the post-establishment stage. In this sense, for the cuttings of aerial biomass production each experimental unit or plot was divided into two halves, where the first was cut at 45 days and the second at 70 days after the homogenization cutting. The forage contained within a frame of 1 square meter was cut and it was then estimated for one hectare.

Statistical analysis. The qualitative variables (all the adaptation and phenology ones) were analyzed through descriptive statistics; while the biomass production was analyzed by the PROG GLM/ANOVA (SAS V 9.2). The means were compared through Tukey's test.

Results

Establishment stage

Vigor. The grasses *F. rubra, D. glomerata,* and *C. clandestinus* (control) stood out for their vigor; while *B. catharticus* and *P. pratense* showed the lowest values. *L. uliginosus* showed similar values independently from the grass, except when it was associated with *H. lanatus* and *D. glomerata* var. Knaulgrass, where the vigor was higher (table 1).

Grass height. The average height was 27,3 cm, with significant differences among accessions (p<0,001), being higher in *B. catharticus* and *H. lanatus* with 39,7 and 42,3 cm, respectively; while *A. odoratum* and *D. glomerata* var. Knaulgrass showed the lowest height (20,0 and 21,3 cm, respectively).

Pests and diseases. The highest incidence of pests and diseases was shown in *F. pratense* and *D. glomerata*, associated to the rust (*Puccina* sp.) attack; while in *B. catharticus* and *H. lanatus* damage on the inflorescence was observed, related to smut. In *L. uliginosus* a damage caused by slugs was visible at the beginning of the establishment stage, but it did not have high incidence and the plants recovered quickly. For the case of *C. clandestinus* no pest and disease incidence appeared (table 1).

Legume cover. In all the accessions good legume cover was shown, with an average value of 90 %, and the association with *P. pratense, A. odoratum* and *F. pretense* stood out with 95 % of cover; however, the association with *D. glomerata* reached 75 % of legume cover (table 1).

Phenology. Only eight of the 11 grass accessions associated with *L. uliginosus* showed flowering; *B. catharticus* and *H. lanatus* were the ones that had a shorter period between transplant and the emergence of inflorescence, with 28 days. The grass with the largest period was *D. glomerata*, with 49 days before flowering; while in the control *C. clandestinus* (naturalized, control), the associations with *C. clandestinus* (introduced) and *C. clandestinus* (naturalized), the early flowering emergence was not visible, and thus it was not evaluated. For the case of the presence of mature

Table 1. Measured variables during the establishment in the grass accessions associated with *L. uliginosus* and the *Cenchrus clandestinus* control.

Treatment	Grass			Legume		
	Height[2], cm	P & D[3]	Vigor[4]	Vigor	Cover[5], %	P & D
[1]*C. clandestinus* (naturalized, control)	24,0[def]	0,0	4,6	-	-	-
B. catharticus	39,7[a]	1,6	4,3	4,7	90	0,0
F. rubra	25,7[bcd]	0,0	4,8	4,6	90	0,3
D. glomerata	29,0[b]	2,1	4,7	4,7	75	0,1
F. arundinacea	28,7[bc]	0,3	4,6	4,7	90	0,0
P. pratense	26,0[bcd]	0,0	4,2	4,7	95	0,0
C. clandestinus 1 (introduced)	23,4[def]	0	4,5	4,7	90	0,1
A. odoratum	20,0[f]	0,0	4,5	4,6	95	0,0
H. lanatus	42,3[a]	1,5	4,5	4,7	90	0,0
D. glomerata (var. Knaulgrass)	21,3[ef]	0,0	4,5	4,7	90	0,0
F. pratense	23,0[def]	2,2	4,4	4,6	95	0,0
C. clandestinus 2 (naturalized)	24,7[cde]	0,0	4,5	4,7	90	0,0
Mean	27,3	0,6	4,5	4,7	90	0,04
SE ±	0,88***	-	-	-	-	-

[1] There was no bug incidence, but there were frosts in the establishment stage.
[2] Height at the end of the establishment stage (180 days since sowing).
[3] P & D =Incidence of pests and diseases from 0 to 5 (0: without affectations and 5: severely affected).
[4] Vigor in scale from 1 to 5 (1: very low, 5: high).
[5] Cover at the end of the establishment stage
Different means in the same column significantly differ at p<0,05, according to Tukey's test. ***p<0,001.

seed *H. lanatus* stood out with the shortest time period in seed maturation, which occurred 14 days after flowering.

Post-establishment stage

Grass height in the rainy season. For this variable in the regrowth frequency of 45 days an average of 31,3 cm was obtained, where significant differences were observed among the grasses (p<0,001). *B. catharticus* stood out with 57,5 cm; while *A. odoratum* and *F. pratense* showed the lowest values (16,5 and 17,0 cm, respectively). In the regrowth frequency of 70 days, a height was reached in the grasses of 37,0 cm with significant differences (p<0,001); the highest value was 63,5 cm in *B. catharticus* and had the lowest value (19,0 cm) in *F. pratense* (table 2).

Grass height in the dry season. During the dry season, the average height at 45 days of regrowth was 27,5 cm, with significant differences (p<0,001) among grasses. The highest height was reached by *B. catharticus* (51,5 cm). In turn, *P. pratense* and *C. clandestinus* (introduced) showed the lowest values (15,0 and 15,5 cm, respectively). In the regrowth frequency of 70 days significant differences (p<0,001) also appeared and average height of 32,3 cm was achieved. In turn, *B. catharticus* stood out with a height of 58,5 cm and *C. clandestinus* (introduced), with the lowest height (table 2).

Total aerial biomass production in the rainy season (RS). In the cutting frequency of 45 days a total aerial biomass production in the RS of 1 347 kg DM/ha was observed, with significant differences for p<0,001 (table 3), and the associations with *F. rubra, F. arundinacea* and *A. odoratum* stood out with 1 764, 1 745 and 1 680 kg DM/ha, respectively; meanwhile, *C. clandestinus* (naturalized, control) showed the lowest production with 624 kg DM/ha.

For the 70-day frequency, the total aerial biomass production in the RS had a value of 1 476 kg DM/ha; significant differences (p<0,001) were observed for production among grass species (table 4). *F. rubra* and *F. arundinacea* reached the highest productions with 2 576 and 2 365 kg DM/ha, respectively; while *F. pratense* showed the lowest one with 168 kg DM/ha. On the other hand, *C. clandestinus* (naturalized, control) showed a value of 1 834 kg DM/ha, which was above the average. Significant differences (p < 0,001) were found in the legume cover in the associations, standing out

Table 2. Average height (cm) in the grass accessions associated with *L. uliginosus* and the *Cenchrus clandestinus* control, during the rainy and dry seasons.

Treatment	Rainy season		Dry season	
	45 days	70 days	45 days	70 days
C. clandestinus (naturalized, control)	25,5^{c}	31,0^{c}	22,5^{cl}	25,5^{d}
B. catharticus	57,5^{a}	63,5^{a}	51,5^{a}	58,5^{a}
F. rubra	38,0^{b}	46,0^{b}	34,0^{b}	39,5^{c}
D. glomerata	40,5^{b}	46,5^{b}	39,5^{b}	46,5^{b}
F. arundinacea	41,0^{b}	48,5^{b}	33,5^{b}	38,5^{c}
Ph. pratense	19,0^{cd}	20,5^{ef}	15,0^{d}	19,0^{e}
C. clandestinus 1 (introduced)	22,5^{cd}	28,5^{cd}	15,5^{d}	19,5^{e}
A. odoratum	16,5^{d}	22,5^{ef}	17,0^{cd}	23,5^{ed}
H, lanatus	52,0^{a}	62,5^{a}	46,0^{a}	51,0^{b}
D. glomerata (var. Knaulgrass)	20,0^{cd}	24,5^{de}	18,5^{cd}	21,0^{ed}
F, pratense	17,0^{d}	19,0^{f}	17,0^{cd}	20,0^{e}
C. clandestinus 2 (naturalized)	25,5^{c}	31,5^{c}	20,5^{cd}	25,5^{d}
Mean	31,3	37,0	27,5	32,3
SE ±	0,39***	0,28***	0,31***	0,26***

Different letters in the same column significantly differ for p<0,05, according to Tukey's test.
***(p<0,001).

Table 3. Total aerial biomass production (kg DM/ha)[1] in the grass accessions associated with *L. uliginosus* and the *C. clandestinus* control during the rainy season[2].

Treatment	Cutting frequency		
	45 days	70 days	Sig[3]
C. clandestinus (naturalized, control)	624[b4]	1 834[bc4]	S
B. catharticus + Legume	1 200[ab]	2 959[abc]	S
F. rubra + Legume	1 764[a]	3 974[ab]	S
D. glomerata + Legume	982[ab]	2 692[abc]	S
F. arundinacea + Legume	1 745[a]	3 793[ab]	S
P. pratense + Legume	1 417[ab]	2 224[abc]	S
C. clandestinus 1 (introduced) + Legume	1 424[ab]	1 685[bc]	NS
A. odoratum + Legume	1 680[a]	4 583[a]	S
H. lanatus + Legume	1 371[ab]	3 465[abc]	S
D. glomerata (var. Knaulgrass) + Legume	1 311[ab]	1 220[c]	NS
F. pratense + Legume	1 279[ab]	1 817[bc]	S
C. clandestinus 2 (naturalized) + Legume	1 365[ab]	1 329[c]	NS
Mean	1 347	2 631	***
SE ±	66,26***	214,57***	

[1] kg DM/ha = kg DM of grass + kg DM of legume, [2] average production of one cutting per each frequency, [3]Significance = Indicates whether there is (S) or there is not (NS) significant difference between cutting frequencies for each accession.
Different letters in the same column differ for p<0,05 according to Tukey's test, *** p < 0,001.

Table 4. Biomass production of the grass (kg DM/ha)[1] and legume percentage during the rainy season[2].

Treatment	Cutting frequency			
	45		70	
	kg DM/ha	Legumes, %	kg DM/ha	Legumes, %
C. clandestinus (naturalized, control)	624[abcd2]	-	1 834[abcd2]	-
B. catharticus	625[abcd]	57,3[abc2]	1 861[abcd]	50,9[cd2]
F. rubra	1 003[a]	60,6[abc]	2 576[a]	50,1[cd]
D. glomerata	812[abc]	22,1[d]	2 156[abc]	27,8[d]
F. arundinacea	805[abc]	64,1[abc]	2 365[ab]	48,9[cd]
Ph. Pratense	261[d]	35,0[cd]	837[ab]	-
C. clandestinus 1 (introduced)	605[abcd]	62,8[abc]	868[abcd]	57,3[bcd]
A. odoratum	832[ab]	62,2[abc]	2 318[ab]	58,4[d]
H. lanatus	822[abcd]	48,[bcd]	1 992[abcd]	45,8[abcd]
D. glomerata (var. Knaulgrass)	431[bcd]	79,9[ab]	475[bcd]	67,8[c]
F. pratense	328[cd]	81,2[ab]	168[d]	94,4[abc]
C. clandestinus 2 (naturalized)	952[a]	35,4[cd]	753[abcd]	53,0[d]
Mean	667	60,8	1 476	58
SE ±	44,57***	3,77***	168,07***	3,44***

***(p<0,001), [1]kg DM/ha= kilograms of grass DM, [2] average production of one cutting per each frequency.

in *F. pratense* with the highest percentage (94,4 %) and in *D. glomerata* with the lowest (27,8 %).

Total aerial biomass production in the dry season (DS). Regarding the total aerial biomass production in the DS in the cutting frequency of 45 days, an average of 663 kg DM/ha was obtained, and significant differences were found (p<0,001) among associations (table 5). *F. pratense* and *B. catharticus* stood out for their higher productions, with 988 and 832 kg DM/ha, respectively; while *C. clandestinus* (naturalized, control) had the lowest production with 348 kg DM/ha.

At the 70-day cutting frequency a grass aerial biomass production of 1 184 kg DM/ha was obtained; and significant differences (p<0,001) were found among the associations (table 5). The highest biomass productions were recorded in *B. catharticus* and *H. lanatus* with 2 009 and 1 721 kg DM/ha, respectively; while the lowest production was obtained in the association with *C. clandestinus* (introduced).

When comparing the total aerial biomass production between the two cutting frequencies, significant differences (p<0,01) were found (table 5). The biomass production in the 70-day cutting was higher, except in *P. pratense, C. clandestinus* 1 (introduced), *D. glomerata* (var. Knaulgrass) and *F. pratense*.

Aerial biomass production in the grass in the DS. In the grass biomass production during the DS in the cutting at 45 days, an average of 510 kg DM/ha was obtained, with significant differences (p<0,001) among accessions (table 6). The highest production was obtained in *B. catharticus* being the one with the (741 kg DM/ha); while *P. pratense* had the lowest production, with 337 kg DM/ha. For the legume cover significant differences (p<0,01) were found among the associations (table 6). The average was 33,2 %, in which the legume stood out in the association with *D. glomerata* var. Knaulgrass (54,1 %); while the associations with *B. catharticus* and *D. glomerata* had the lowest values (15,0 and 15,9 %, respectively).

In the 70-day frequency a general average of 917 kg DM/ha was reached, with significant differences (p<0,001) for the grass biomass produc-

Table 5. Total aerial biomass production (kg DM/ha)[1] in the grass accessions associated with L. uliginosus and the *Cenchrus clandestinus* control during the dry season[2].

Treatment	Cutting frequency		
	45 days	70 days	Sig[3]
C. clandestinus (naturalized, control)	348[c4]	1 182[abcd4]	S
B. catharticus + Legume	832[ab]	2 009[a]	S
F. rubra + Legume	804[ab]	1 682[abc]	S
D. glomerata + Legume	772[abc]	1 114[abcd]	S
F. arundinacea + Legume	776[abc]	1 715[ab]	S
Ph. pratense + Legume	639[abc]	865[bcd]	NS
C. clandestinus 1 (introduced) + Legume	501[bc]	578[d]	NS
A. odoratum + Legume	545[bc]	1 152[abcd]	S
H. lanatus + Legume	647[abc]	1 721[ab]	S
D. glomerata (var. Knaulgrass) + Legume	596[abc]	675[d]	NS
F. pratense + Legume	988[a]	768[cd]	NS
C. clandestinus 2 (naturalized) + Legume	507[bc]	749[d]	S
Mean	663	1 184***	**
SE ±	40,63***	76,48***	

** p < 0,01, *** p < 0,001. [1] (kg DM/ha) = kg DM of grass + kg DM legume.
[2] Average of two cuttings. [3] Sig = Indicates whether there is (S) or there is not (NS) significant difference between cutting frequencies for each accession (P<0,05). [4] The means followed by equal letters in the same column are not significantly different (P<0,05), according to Tukey's test.

tion (table 4). *B. catharticus* (1 537 kg DM/ha), *F. arundinacea* (1 512 kg DM/ha) and *H. lanatus* (1 421 kg DM/ha) stood out with the highest productions; while *C. clandestinus* (int.) and *D. glomerata* (var. Knaulgrass) had the lowest production with 350 and 370 kg DM/ha. *C. clandestinus* (naturalized, control) showed a production above the average with 1 182 kg DM/ha.

Regarding the legume proportion, significant differences (p < 0,001) were found among associations (table 6), with an average of 33,2 and 32,9 % for the cutting frequency of 45 and 70 days, respectively. The legume stood out when it was associated with *D. glomerata* (var. Knaulgrass), with the highest proportion, followed by *P. pratense* and *F. pratense*; while the one associated with *D. glomerata* showed the lowest proportion.

Discussion

Establishment stage. During the establishment stage all the accessions were observed to have an adequate adaptation to the environment, but in the treatments with *F. arundinacea* and *D. glomerata,* the grass showed problems due to *Puccina* sp. (rust), which coincides with reports made in other studies, where it is proven that these materials and other grasses are susceptible to rust incidence (Novotná *et al*., 2017).

On the other hand, *L. uliginosus* showed an excellent performance in this stage; although it showed slow growth during the beginning of the experiment, which coincides with the report by Marley *et al.* (2006), under similar conditions to the ones in this study (Castillo *et al*., 2017). The difference in the values found for grass height at the end of the establishment stage is directly associated with the growth physiology of each species (because grasses of erect, semi-erect and prostrate habit were evaluated), which is reflected on the results that were reached in such variable (table 1).

Regarding the legume cover, it was observed that all the accessions, with the exception of *D. glomerata*, had good growth. In some cases the grass was partially displaced, as in the associations with *P. pratense, F. pratense* and *A. odoratum*. This is related to the prostrate growth habit of this legume (Castillo *et al*., 2017).

Table 6. Aerial biomass production of the grasses (kg DM/ha)[1] and proportion of legume (%) during the dry season[2].

Treatment	Cutting frequency			
	45		70	
	kg DM/ha	Legume ,%	kg DM/ha	Legume, %
C. clandestinus (naturalized, control)	348^{de3}	-	1 182^{abc3}	-
B. catharticus	741^{a}	15,0^{c3}	1 537^{a}	23,9^{ab3}
F. rubra	645^{abc}	25,3^{bc}	1 307^{ab}	28,8^{ab}
D. glomerata	690^{ab}	15,9^{c}	1 031^{abcd}	9,3^{b}
F. arundinacea	599^{abcd}	22,5^{bc}	1 512^{a}	18,3^{ab}
P. pratense	337^{e}	41,7^{abc}	482^{cd}	48,2^{a}
C. clandestinus 1 (introduced)	360^{d}	49,6^{ab}	350^{d}	44,3^{a}
A. odoratum	394^{d}	38,5^{abc}	791^{abcd}	39,0^{ab}
H. lanatus	499^{bcd}	28,3^{abc}	1 421^{a}	24,1^{ab}
D. glomerata (var. Knaulgrass)	346^{e}	54,1^{a}	373^{d}	49,2^{a}
F. pratense	726^{a}	47,8^{ab}	443^{cd}	47,8^{a}
C. clandestinus 2 (naturalized)	437^{cd}	23,2^{bc}	574^{bcd}	27,6^{ab}
Mean	510	33,2	917	32,9
SE ±	33,52***	2,92**	68,78***	2,53**

[NS] Not significant (p>0,05), **(p<0,01), ***(p<0,001).
[1] (kg DM/ha) = kg of grass DM, [2] Average of two cuttings, [3] The means followed by equal letters in the same column are not significantly different (P<0,05), according to Tukey's test.

With regards to the grass phenology, the species such as *B. catharticus, H. lanatus* and *F. arundinacea* showed early flowering and abundant seed production, characteristic that can be useful to multiply these materials in field and identify the optimum moment of pasture grazing and management during the establishment.

Post-establishment stage

Total aerial biomass production. The associations showed higher biomass production in the two cutting frequencies during the rainy season. In turn, in biomass production at 45 days in the RS higher values were observed than those reported by other authors, such as Corredor (1986), who found productions of 930 kg DM/ha in *F. arundinacea* associated with *T. repens* in this period.

In some studies the reports are expressed in kg DM/ha/year; the possible number of cuttings to be performed during the year according to the frequencies should be taken into consideration. In this sense, cuttings every 45 days represent 8,1 cuttings/year that are equivalent to 10 910,7 kg DM/ha/year; while cutting every 70 days is equivalent to 5,2 cuttings/year, which would mean 13 681,2 kg DM/ha/year.

Taking the above-explained facts into consideration, reports have been found like those by Mendoza (1988), with productions of up to 14 440 kg DM/ha/year in *C. clandestinus* associated with *T. repens*, higher value than the ones observed in this study, in the DS as well as the RS (table 3). Nevertheless, under grazing conditions these species are used with lower resting periods than 35 days in some cases (Posada-Ochoa *et al*., 2013; Dimaté-Gil, 2016).

On the other hand, Navas (1972) observed in *B. catharticus*, associated with *T. repens* values of 2 400 kg DM/ha/year, lower value than the one found in the DS for the two cutting frequencies of this study. Also in the Mosquera zone, Cundinamarca, in Colombia, productions are reported in *F. arundinacea* pastures with *L. uliginosus* of up to 2 282 kg DM/ha with cuttings at 45 days, higher than the value observed in this study (Castro *et al*., 2009), but lower than others reported in the western Bogotá Savanna in *P. clandestinus* + *L. uliginosus* pastures (4 012 kg DM/ha) and in *F. arundinacea* + *L. uliginosus* (4 168 kg DM/ha), which was due to the fact that they were well prepared and adequately fertilized lands (Morales *et al*., 2013).

In other zones, Leep *et al.* (2002), found in *F. arundinacea* associated with *L. corniculatus* 1 000 kg DM/ha/year; on the other hand, in *L. uliginosus* used as protein bank for grazing in sheep, higher productions than 1 300 kg de MS/ha have been found (Piaggio *et al*., 2015).

Biomass production in the grass. ICA (1987) suggested that under good management conditions *F. arundinacea* and *B. catharticus* can produce from 20 000 to 30 000 kg DM/ha/year, which coincides with more recent studies (Castro *et al*., 2009; Morales *et al*., 2013).

In other latitudes similar, or sometimes higher, productions have been reported than the ones in this study for the pure grasses; this is the case of *F. arundinacea*, with productions between 2 500 and 3 500 kg DM/ha (Malcolm *et al*., 2015; Carlsson *et al*., 2017). Also in *Dactylis glomerata*, alone and associated with *Lolium perenne* and *Trifolium repens*, productions have been observed of 20 100 kg DM/ha/year in the mixture and 12 100 kg DM/ha/year in monocrop, which proves the benefit of associating grasses and legumes (Maldonado *et al*., 2017).

Most of the reported productions of the grass are higher than the ones in this study; however, it must be taken into consideration that the sampling was carried out jointly for the grass and the legume per square meter, and not for the grass alone as in the control. This explains the inferiority of the productions with regards to studies conducted in pure grasses. However, when comparing the total aerial biomass production of this study, in most cases it was higher than the ones reported in other works.

Regarding the legume proportion, it was higher in the rainy season than in the dry season, which coincides with the report by Corredor (1986), with 29,7 % in the DS and 44,8 % in the RS in association of *T. repens* with *F. arundinacea*. In addition, the low proportion of legume in the association with *D. glomerata* can be directly related to allelopathic factors of the grass on this species, as reported by Chung and Miller (1995) and Aldana *et al.* (2016) in different grasses, including *F. arundinacea* and *D. glomerata*, where they observed how the aqueous extracts of these plants affected the germination and growth of *M. sativa* crops. In other studies similar or higher productions are reported with legume proportions from 30 to 50 %, using *D. glomerata* alone and associated with *L. perenne* and *T. repens*, with production of up to 21 000 kg DM/ha/year in the proportion of 40 % legume (Rojas-García *et al.*, 2016).

Conclusions

The associations that had the best performance were *F. arundinacea* and *C. clandestinus*, the naturalized as well as the introduced one, which stood out for their higher resistance to pests and diseases during the establishment stage, showing the potential of this type of system as a viable option for the high Colombian Andean tropic.

The associations that stood out for their higher aerial biomass production were *F. rubra, F. arundinacea,* and *A. odoratum*, for the two evaluated cutting ages. The legume proportion was higher than 40 % in all the associations for the two cutting frequencies, except with *D. glomerata*, where it was barely found in 25 %, value below the average in each season.

Acknowledgements

The authors thank the National University, Bogotá campus, for funding this study, as well as the Colombian Corporation of Animal Husbandry Research (AGROSAVIA) for co-authoring it.

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Received: October 26, 2018
Accepted: December 4, 2018