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Research Paper

Dry matter accumulation and crude protein concentration in *Brachiaria* spp. cultivars in the humid tropics of Ecuador

Acumulación de materia seca y concentración de proteína cruda en cultivares de Brachiaria *spp. en el trópico húmedo de Ecuador*

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Abstract

Climatic conditions throughout the year and age of plants affect both yield and quality of forage grasses. In this research, we evaluated the effects of age of regrowth and seasonal conditions on dry matter accumulation and crude protein concentration in 5 cultivars of *Brachiaria* spp.: Señal, Xaraés, Marandú, Piatá and Mulato II, harvested at 2, 4, 6, 8 and 10 weeks after a uniformity cut, during the rainy and dry seasons. The variables were: total dry matter (TDM), leaf dry matter (LDM) and stem dry matter (SDM) yields, leaf area index (LAI), specific leaf area (SLA) and crude protein (CP) concentration. For TDM yield, in the rainy season there was no significant difference (P>0.05) among cultivars, with mean DM yield over 10 weeks of 6.34 t/ha; however, during the dry season Xaraés presented a higher (P<0.05) yield over 10 weeks than other cultivars (5.09 vs. 3.14–3.89 t/ha). Overall, mean DM yield in the dry season was only 62% of that in the wet season. In both periods, Señal tended to have the highest SDM yields, while Xaraés had the greatest (P<0.01) LDM yields in the dry season. Mulato II tended to have the highest CP concentrations throughout, especially in the dry season. This study was conducted in plots with plants only 12 weeks old at commencement. However, it indicated that all cultivars performed well and larger-scale studies of longer duration are warranted to test these cultivars under grazing, especially Mulato II, which showed both high dry matter yield and retention of high protein concentration throughout the study.

Keywords: *Brachiaria decumbens*, *Brachiaria brizantha*, *Brachiaria* hybrid cv. Mulato II, leaf area index, specific leaf area.

Resumen

En la finca experimental “El Oasis” de la Escuela de Ingeniería Agropecuaria, Universidad Tecnológica Equinoccial, Campus Santo Domingo, Ecuador, en un suelo Andosol se evaluaron los efectos de la edad de rebrote y la época del año sobre la acumulación de materia seca y la concentración de proteína bruta en 5 cultivares de *Brachiaria*: Señal (*B. decumbens*), Xaraés (*B. brizantha*), Marandú (*B. brizantha*), Piatá (*B. brizantha*) y Mulato II (*Brachiaria* híbrido), cosechados a 2, 4, 6, 8 y 10 semanas después de un corte de uniformidad, durante las estaciones lluviosa y seca. Las variables evaluadas fueron la materia seca (MS) total, MS de hoja y de tallo, el índice de área foliar, el área foliar específica y la concentración de proteína bruta. El rendimiento de MS total a 10 semanas de rebrote (6.34 t/ha en

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promedio) en la estación de lluvias no varió entre cultivares (P>0.05) mientras en la estación seca el cv. Xaraés presentó el mayor rendimiento (P<0.05) en comparación con los demás cultivares (5.09 vs. 3.14–3.89 t/ha). El rendimiento de MS total en la época seca fue sólo el 62% del obtenido en la época de lluvia. En ambos períodos, el cv. Señal tendió a tener los rendimientos de MS de tallos más altos, mientras que el cv. Xaraés presentó los mayores rendimientos de MS de hojas (P<0.01) en la estación seca. El cv. Mulato II tendió a tener las mayores concentraciones de proteína bruta en ambas épocas, especialmente en la seca. Este estudio se realizó en parcelas con plantas de sólo 12 semanas de edad al inicio. Sin embargo, indicó que todos los cultivares se comportaron satisfactoriamente y estudios a mayor escala y de mayor duración se justifican para probar estos cultivares bajo pastoreo, especialmente el cv. Mulato II que mostró tanto un alto rendimiento de MS como una retención de alta concentración de proteína a lo largo del estudio.

Palabras clave: Área foliar específica, *Brachiaria decumbens*, *Brachiaria brizantha*, *Brachiaria* híbrido cv. Mulato II, índice de área foliar.

Introduction

Poor grassland productivity is one of the most important limitations in the dual-purpose cattle system in the Ecuadorian tropics (Avellaneda et al. 2008), because most grazing areas are sown with forage species such as *Brachiaria humidicola*, *Brachiaria decumbens* and *Brachiaria brizantha* (Vera 2004). These grasses have limitations in productivity, adaptability and persistence in these environments; in addition, they are susceptible to the spittlebug of pastures caused by *Aeneolamia* spp. (Cardona et al. 2006) and foliar fungi such as *Rhizoctonia solani*, which significantly reduce productivity (Álvarez et al. 2013). However, new cultivars of the genus *Brachiaria* have been released to the market as options to overcome the problems observed in traditional forages, thus providing better fodder options (Pizarro et al. 2013).

In Ecuador, several cultivars of *Brachiaria* spp. are available that have potential for increasing the productivity of existing grass production systems (Faría Mármol 2006; Miles 2006). Jácome and Suquilanda (2014) indicated that cultivars Mulato I and Xaraés are well accepted by farmers because of their high nutritional value, adaptation to a range of soils and resistance to or tolerance of pests and diseases (Cardona et al. 2006; Argel 2008).

The productive capacity of forage species can be modified by changing various factors, such as: using different genotypes or cultivars; modifying the agronomic management and age of the plants at harvest; and by weather conditions throughout the year (Zaragoza et al. 2009; Lara et al. 2010). It is therefore important to assess the dynamics of herbage accumulation of different pasture species and to understand the impact of seasonal changes (Fagundes et al. 2005) on the pattern of growth, quality and chemical composition of pasture plants, in order to optimize their use and plan an appropriate agronomic management strategy for grasslands (Avellaneda et al. 2008). Based on the above, this research aimed to evaluate the effects of plant regrowth age and seasonal conditions on the accumulation of dry matter and crude protein concentration in 5 cultivars of *Brachiaria* spp. in the humid tropics of Ecuador.

Materials and Methods

The research was conducted under field conditions from December 2011 to November 2012, at the experimental farm "El Oasis", property of the Escuela de Ingeniería Agropecuaria of the Universidad Tecnológica Equinoccial, Campus Santo Domingo, Ecuador (00°13'20" S, 79°15'39" W; 406 masl). The experimental site has a predominantly humid tropical climate, with annual average temperature of 23.4 °C and annual rainfall of 2,600–3,500 mm with 2 seasons, defined as rainy and dry (SENPLADES 2015). The monthly rainfall and mean maximum and minimum temperatures during the evaluation period are reported in Figure 1.

In this research 5 *Brachiaria* cultivars were used: Señal (*B. decumbens*, considered as the control since it is most widely cultivated in the area); Marandú (*B. brizantha*), Piatá (*B. brizantha*), Mulato II (*Brachiaria* hybrid) and Xaraés (*B. brizantha*); and these were harvested at 5 growth stages (2, 4, 6, 8 and 10 weeks after an initial harvest) during the rainy (March–May) and dry (September–November) seasons to monitor the rate of DM accumulation over time and assess quality aspects.

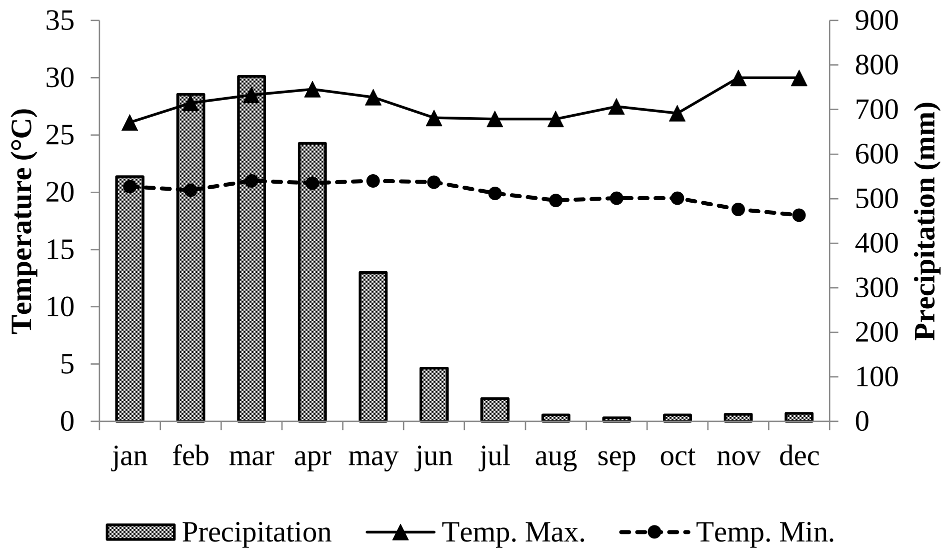

Figure 1. Monthly precipitation and mean maximum and minimum temperatures during 2012 at the Climatological Station of the Universidad Tecnológica Equinoccial, Campus Santo Domingo, Ecuador.

A randomized complete block design in an arrangement in divided plots was used, where the large plot was the cultivar and the subplots the ages of regrowth. On 3 December 2011, seeds of each cultivar were placed in bags (3 seeds/bag) of black polyethylene with a capacity of approximately 2 kg of soil, to ensure one plant survived per bag and placed in a greenhouse. At 6 weeks after seedling emergence (21 January 2012; 7 weeks after sowing), the plants were transplanted to large plots of 5 x 5 m (25 m^2), leaving an intra-row and inter-row spacing of 0.50 m. The useful area within each large plot was 3 x 3 m, divided into 9 quadrants of 1 m^2 (subplots), of which 5 subplots were randomly selected to represent each age of regrowth (2, 4, 6, 8 and 10 weeks). The soil of the experimental site is of volcanic origin (Andosol) and a soil sample was taken using a 5-point method to 20 cm depth to provide the physicochemical analyses shown in Table 1. All plots were fertilized after transplanting with 120 kg N/ha (as urea), 60 kg P/ha (as Daphos), 70 kg K/ha (as KCl), 60 kg Mg/ha (as magnesium oxide) and 50 kg S/ha (as ammonium sulfate).

In the sixth week after transplantation the plants were 80–100 cm tall with 45–65 tillers/plant; senescent material was obvious in the lower stratum, so we applied an initial uniformity cut on 3 March 2012 to 15 cm above ground level. The evaluation during the rainy season then followed. At the end of this period (12 May 2012), the plots were allowed to stand for 15 weeks, when a second uniformity cut was applied on 1 September 2012. The dry season evaluation then followed. In each season, observations commenced 2 weeks after each uniformity cut to measure: accumulation of total (TDM), leaf (LDM) and stem (SDM) dry matter; plant height (PH); leaf area index (LAI); specific leaf area (SLA); and crude protein concentration (CP). During each sampling for the relevant cutting treatment we measured the height of plants from ground level to ligule of the fully developed leaf and harvested the forage at 15 cm above ground level from the relevant 1 m^2 subplot (4 plants). The harvested forage (green matter) was weighed on a precision scale (Model PB3002-S, Mettler Toledo) and 2 subsamples were taken, the first (approximately 200 g) to define the proportions of leaf (leaf blade + sheath) and stem after separating these components. Leaves from this subsample were used for leaf area estimation as well. A multifunctional printer scanner (HP Photosmart D110) was employed using the methodology reported by Rincón et al. (2012). The second subsample (approximately 1 kg) was used to determine CP concentration by the Kjeldahl method (N x 6.25) (AOAC 2000); CP% was determined only for 4, 6 and 8 week cuttings. All samples were dried in a forced-air oven at 65 °C for 48 h to estimate the dry matter (DM) concentration and calculate DM yields.

The data were analyzed in time within season by using PROC GLM of SAS (SAS Institute 2010), in a complete randomized block design in an arrangement in divided plots. Tukey's Studentized range tests ($P \leq 0.05$) were performed, when treatments were significantly different in each season.

Table 1. Chemical[1] characteristics of the soil used in the experiment[2].

pH	OM[3]	NH_4	P	S	Fe	Cu	Zn	Mn	B	K	Ca	Mg
	(%)				(mg/kg)						(cmol/kg)	
5.9	2.2	41.0	6.5	6.3	42.0	5.6	1.9	2.8	0.3	0.3	8.3	2.9

[1]Obtained in the Chemistry Laboratory, Universidad Tecnológica Equinoccial, Campus Santo Domingo.
[2]The analysis to determine the phosphorus concentration in the soil was performed by the method of Olsen modified with a solution of sodium bicarbonate and EDTA adjusted to pH 8.5 with 10N NaOH.
[3]The organic matter (OM) analysis was performed using the method of Walkley Black, suitable for the conditions of Ecuador.

Results

Total dry matter accumulation

Accumulation of total dry matter (TDM) followed an exponential pattern in both rainy and dry seasons (Table 2). There were no significant differences (P>0.05) in TDM accumulation among cultivars of *Brachiaria* during the rainy season, with yields ranging from 5.83 to 6.87 t DM/ha (mean 6.34 t DM/ha) over the 10 week period. However, in the dry season differences between cultivars (P<0.01) were observed in each of the regrowth periods. While there was little consistency in which cultivars were superior within particular cutting frequencies, cultivar Xaraés accumulated the greatest amount of TDM during the later part of the dry season and produced the highest DM yield during the dry season period (5.09 t DM/ha), with the remaining cultivars producing 3.14–3.89 t DM/ha. Average accumulation of TDM during the dry season was 62% of that produced in the rainy season.

Leaf dry matter accumulation

Leaf dry matter (LDM) yield during the rainy season varied between cultivars at the various cutting ages but at the tenth week, there were no significant differences in leaf yield between cultivars (P>0.05; Table 3). On the other hand, during the dry season, significant differences (P<0.05) in leaf yield between cultivars at all ages of regrowth were observed. Towards the end of the dry season (8 and 10 week cuttings) Xaraés produced more leaf (P<0.05) than most other cultivars. Dry season leaf yield at the 10 week cutting varied from 4.28 t DM/ha (Xaraés) to 2.50 t DM/ha (Marandú) (P<0.001).

Table 2. Total dry matter yields at different ages of regrowth of 5 *Brachiaria* cultivars during the rainy (March–May) and dry (September–November) seasons in humid tropical conditions of Ecuador.

Cultivar	Total dry matter (t/ha)									
	Rainy season					Dry season				
	Age of regrowth (weeks)					Age of regrowth (weeks)				
	2	4	6	8	10	2	4	6	8	10
Señal	0.24	0.96	2.96	4.02	6.87	0.16	0.39	0.75	1.98	3.69
Marandú	0.24	0.85	2.54	4.00	5.83	0.23	0.42	0.73	1.59	3.14
Mulato II	0.29	1.31	2.66	4.33	6.57	0.13	0.28	0.64	1.95	3.76
Piatá	0.28	1.13	2.36	4.36	6.14	0.13	0.41	0.91	1.93	3.89
Xaraés	0.32	1.28	3.16	4.49	6.27	0.13	0.41	0.87	2.49	5.09
Mean	0.27	1.11	2.73	4.24	6.34	0.16	0.38	0.78	1.99	3.92
LSD[1]	0.09	0.29	1.05	1.59	2.38	0.04	0.1	0.19	0.54	1.09
LS[2]	0.058	<0.001	0.177	0.812	0.686	<0.001	0.005	0.004	0.003	0.001

[1]Least Significant Difference (Tukey P≤0.05).
[2]Level of significance.

Table 3. Leaf dry matter yields at different ages of regrowth of 5 *Brachiaria* cultivars during the rainy (March–May) and dry (September–November) seasons in humid tropical conditions of Ecuador.

Cultivar	Leaf dry matter (t/ha)									
	Rainy season					Dry season				
	Age of regrowth (weeks)					Age of regrowth (weeks)				
	2	4	6	8	10	2	4	6	8	10
Señal	0.21	0.75	1.71	1.85	3.13	0.16	0.35	0.66	1.55	2.76
Marandú	0.24	0.79	1.76	2.49	3.46	0.23	0.42	0.72	1.48	2.50
Mulato II	0.29	1.26	1.90	2.66	3.85	0.13	0.28	0.63	1.88	3.19
Piatá	0.28	0.97	1.60	2.60	3.21	0.13	0.41	0.88	1.66	3.02
Xaraés	0.32	1.20	2.45	3.50	4.18	0.13	0.41	0.87	2.34	4.28
Mean	0.27	1.00	1.88	2.62	3.57	0.16	0.37	0.75	1.78	3.15
LSD[1]	0.08	0.24	0.76	0.93	1.17	0.04	0.10	0.19	0.52	1.01
LS[2]	0.017	<0.001	0.029	0.002	0.072	<0.001	0.004	0.002	0.001	0.001

[1]Least Significant Difference (Tukey P≤0.05).
[2]Level of significance.

Stem dry matter accumulation

As for leaf production, stem dry matter (SDM) accumulation during the rainy season varied between cultivars from the second to the sixth week (P<0.01). At the 8 and 10 week cuts cultivars Señal and Piatá tended to have the highest stem yields and Xaraés the lowest but differences were not significant (P>0.05; Table 4). During the dry season, SDM accumulation followed an exponential pattern, with greatest stem production between the 8 and 10 week cuts. At the 10 week cut, cultivars Señal and Piatá had the highest SDM (0.93 and 0.87 t DM/ha, respectively), while Marandú and Mulato II had the least (0.64 and 0.57 t DM/ha) (P<0.001).

Plant height

During the rainy season plant height of the different cultivars varied but by the eighth and tenth weeks Señal was shorter than all other cultivars (P<0.001; Table 5). During the dry season Piatá, Señal and Xaraés progressively showed superiority in height over the other cultivars and by the tenth week Piatá and Xaraés were taller than all others (P<0.01).

Table 4. Stem dry matter yields at different ages of regrowth of 5 *Brachiaria* cultivars during the rainy (March–May) and dry (September–November) seasons in humid tropical conditions of Ecuador.

Cultivar	Stem dry matter (t/ha)									
	Rainy season					Dry season				
	Age of regrowth (weeks)					Age of regrowth (weeks)				
	2	4	6	8	10	2	4	6	8	10
Señal	0.03	0.20	1.22	1.69	2.81	-	0.04	0.09	0.41	0.93
Marandú	-	0.06	0.78	1.39	1.95	-	-	0.02	0.11	0.64
Mulato II	-	0.05	0.76	1.43	2.09	-	-	0.01	0.08	0.57
Piatá	-	0.16	0.76	1.62	2.61	-	-	0.03	0.27	0.87
Xaraés	-	0.08	0.71	1.00	1.86	-	-	0.01	0.15	0.80
Mean	-	0.11	0.84	1.43	2.26	-	-	0.03	0.21	0.76
LSD[1]	-	0.07	0.37	0.82	0.95	-	-	0.02	0.10	0.22
LS[2]	-	<0.001	0.005	0.127	0.068	-	-	<0.001	<0.001	0.001

[1]Least Significant Difference (Tukey P≤0.05).
[2]Level of significance.

Table 5. Plant height at different ages of regrowth of 5 *Brachiaria* cultivars during the rainy (March–May) and dry (September–November) seasons in humid tropical conditions of Ecuador.

Cultivar	Plant height (cm)									
	Rainy season					Dry season				
	Age of regrowth (weeks)					Age of regrowth (weeks)				
	2	4	6	8	10	2	4	6	8	10
Señal	43.1	53.5	81.8	95.4	80.2	29.6	42.5	70.4	91.3	77.5
Marandú	40.3	48.8	77.2	117.1	129.8	32.4	30.0	41.5	55.0	67.8
Mulato II	47.7	57.3	83.5	108.3	129.2	32.5	31.2	43.1	57.9	75.8
Piatá	45.8	63.8	98.8	132.1	137.1	32.0	39.2	65.7	95.4	105.5
Xaraés	54.5	71.6	91.2	126.3	137.8	32.3	48.3	71.0	91.3	103.5
Mean	46.3	59.0	86.5	115.8	122.8	31.8	38.2	58.4	78.2	86.0
LSD[1]	9.4	10.6	14.3	10.1	19.8	10.1	9.1	16.5	16.8	23.8
LS[2]	0.005	0.001	0.003	<0.001	<0.001	0.879	<0.001	<0.001	<0.001	<0.001

[1]Least Significant Difference (Tukey P≤0.05).
[2]Level of significance.

Leaf area index

During the rainy season, the leaf area index (LAI) followed a linear pattern for all cultivars, increasing from a mean of 0.6 at week 2 to 5.3 at week 10 (Table 6). The cultivars Mulato II and Xaraés reached the highest LAI at week 10 of 6.6 and 5.8, respectively. Throughout the wet season Piatá had lower LAI than most other cultivars (P<0.001). During the dry season, LAI followed an exponential pattern with the highest increase from the sixth week. As for the wet season, Piatá showed lower LAI than Xaraés and Mulato II by week 10 (P<0.05).

Specific leaf area

Specific leaf area (SLA) declined in all cultivars during both rainy and dry seasons (Table 7). Piatá tended to have the lowest SLA throughout the wet season, while Señal, Mulato II and Marandú presented the highest values. In the dry season, cultivar differences again emerged with Mulato II, Marandú and Señal having the greatest SLA and Xaraés and Piatá the lowest (P<0.01).

Crude protein concentration

Data for weeks 4, 6 and 8 on whole plant samples are presented in Table 8. Differences in crude protein concentration (P<0.05) between cultivars were observed in both rainy and dry seasons, where Mulato II presented the highest concentration at most observations. In both seasons, mean crude protein concentration decreased as the regrowth age increased, declining from 14.1% to 9.1% in the wet season and from 12.6% to 7.6% in the dry season.

Table 6. Leaf area index at different ages of regrowth of 5 *Brachiaria* cultivars during the rainy (March–May) and dry (September–November) seasons in humid tropical conditions of Ecuador.

Cultivar	Leaf area index									
	Rainy season					Dry season				
	Age of regrowth (weeks)					Age of regrowth (weeks)				
	2	4	6	8	10	2	4	6	8	10
Señal	0.5	2.0	3.2	3.7	5.1	0.4	0.9	1.2	2.7	4.8
Marandú	0.6	1.8	3.1	4.3	5.4	0.7	1.0	1.6	2.5	4.4
Mulato II	0.8	2.6	3.8	4.7	6.6	0.3	0.8	1.4	3.6	5.8
Piatá	0.5	1.3	2.1	3.4	3.8	0.3	0.7	1.4	2.2	3.6
Xaraés	0.7	1.9	3.5	4.9	5.8	0.3	0.9	1.6	3.6	5.9
Mean	0.6	1.9	3.1	4.2	5.3	0.4	0.9	1.4	2.9	4.9
LSD[1]	0.2	0.4	1.0	1.1	1.2	0.2	0.2	0.3	0.9	2.2
LS[2]	0.001	<0.001	0.002	0.004	<0.001	<0.001	0.045	0.016	0.001	0.03

[1]Least Significant Difference (Tukey P≤0.05).
[2]Level of significance.

Table 7. Specific leaf area at different ages of regrowth of 5 *Brachiaria* cultivars during the rainy (March–May) and dry (September–November) seasons in humid tropical conditions of Ecuador.

Cultivar	Specific leaf area (cm^2/g)									
	Rainy season					Dry season				
	Age of regrowth (weeks)					Age of regrowth (weeks)				
	2	4	6	8	10	2	4	6	8	10
Señal	229	246	181	190	151	248	232	173	163	164
Marandú	242	216	168	163	145	273	221	213	158	162
Mulato II	268	190	187	165	162	238	279	210	178	168
Piatá	156	129	125	124	112	221	173	148	125	112
Xaraés	207	148	134	130	132	237	213	170	142	129
Mean	221	186	159	154	140	243	224	183	153	147
LSD[1]	29	30	41	40	34	85	39	25	28	27
LS[2]	<0.001	<0.001	0.001	0.001	0.005	0.433	<0.001	<0.001	<0.001	<0.001

[1]Least Significant Difference (Tukey P≤0.05).
[2]Level of significance.

Table 8. Crude protein concentration at different ages of regrowth of 5 *Brachiaria* cultivars during the rainy (March–May) and dry (September–November) seasons in humid tropical conditions of Ecuador.

Cultivar	Crude protein concentration (%)					
	Rainy season			Dry season		
	Age of regrowth (weeks)			Age of regrowth (weeks)		
	4	6	8	4	6	8
Señal	13.4	11.2	9.0	11.6	7.3	6.5
Marandú	14.0	12.1	8.8	13.4	8.6	8.1
Mulato II	14.6	12.5	10.1	14.3	10.1	10.2
Piatá	13.8	10.9	8.9	12.2	8.3	6.8
Xaraés	14.6	11.1	8.6	11.6	7.4	6.5
Mean	14.1	11.6	9.1	12.6	8.3	7.6
LSD[1]	0.9	1.1	0.8	0.9	1.3	3.4
LS[2]	0.007	0.003	0.001	<0.001	<0.001	0.022

[1]Least Significant Difference (Tukey P≤0.05).
[2]Level of significance.

Discussion

This plot study has provided useful information on the potential of the *Brachiaria* cultivars for use in pastures of humid tropical Ecuador. While the grasses were planted from seed, were only 12 weeks old at commencement of observations and the study was in only a single year, the excellent growth obtained and CP levels maintained indicate that these pastures can be very productive under these conditions. In fact, the DM yields obtained over only 10 weeks in pastures that were only 12 weeks old at commencement are quite remarkable. Further studies under field conditions would clarify how well these preliminary findings can be extrapolated to commercial situations.

The absence of cultivar differences in total DM production during the rainy season in this study was similar to the findings of Rojas-Hernández et al. (2011) for *B. decumbens*, *B. brizantha* cv. Libertad, *B.* hybrid cv. Mulato I and cultivars of *B. humidicola.* Those authors also failed to demonstrate any significant differences in total DM production. However, the differences we showed in proportions of leaf and stem in the different cultivars are important, as we showed higher production of leaves and higher CP concentration than Reyes-Purata et al. (2009). The reduction in growth in these cultivars during the dry season was not surprising, as the major climatic factors that determine forage production are precipitation and temperature (Gerdes et al. 2000; Cuadrado et al. 2004). Rainfall in the rainy season and hence soil moisture was much higher than in the dry season and minimum temperatures were also lower in the dry season. The reduction in TDM yield in the dry season was somewhat lower than the 50% reduction reported by Benítez et al. (2007). This marked reduction in yield accompanied by a drop in CP concentration indicates the reduced carrying capacity of these pastures during the dry season.

The differences between cultivars in leaf DM yield we found in this study may be due to *B. decumbens* and *B. brizantha* having different rates of elongation in leaves (Dias-Filho and Carvalho 2000). In this regard, elongation rates in leaves of 2.5 and 3.5 cm/d and leaf percentages in total DM of 54 and 77% in *B. decumbens* and *B. brizantha*, respectively, have been reported by Guenni et al. (2005). In addition, Hare et al. (2009) reported that Xaraés and Mulato II have higher foliar DM yields than other *Brachiaria* cultivars, especially during the dry season. Similarly, Gerdes et al. (2000) reported a significant decrease in the accumulation of total DM during the period of minimum precipitation, with as much as 98% of the accumulation corresponding to leaf DM.

The pattern of stem DM accumulation during both periods would have been determined by environmental conditions that affected growth of the cultivars. Stem production during the dry season is reduced (Cab et al. 2008) due to stress caused by soil moisture deficiency, curbing the growth of the plant and reducing stem growth (Cruz et al. 2011a). Cruz et al. (2011b) reported that season has a marked effect on the relative growth of leaf and stem, and differences between stem elongation rates of 1.2, 0.8 and 0.6 mm/stem/d in Señal, Xaraés and Marandú, respectively, have been reported by Paciullo et al. (2011). The marked reduction in stem growth in the dry season results in increases in leaf:stem ratios in this season as found in this study. Leaf:stem ratios also declined significantly as plants matured and the proportion of stem in the forage increased.

Plant height was affected to a greater extent by seasonal conditions than by cultivar. Marandú has been shown to be quite susceptible to stress caused by soil water deficiency, presenting taller plants in the rainy season (67 cm) and shorter ones in the dry season (36 cm) at 35 d of regrowth (Gerdes et al. 2000). On the other hand, *B. decumbens* presented lower height, due to its decumbent growth habit, which is characteristic of this species (Pérez et al. 1999). In this study, *B. brizantha* cultivars were taller than the *Brachiaria* hybrid and *B. decumbens*, which agrees with what was reported by Gómez et al. (2000).

The differences among cultivars for LAI may be because some species such as *B. decumbens* are shorter than *B. brizantha*, and there is a positive correlation between plant height and LAI (Guenni et al. 2005). In addition, LAI increases as the plant grows (Gómez-Carabalí et al. 1999), and this increase is closely related to tillering of the crop and soil cover (Rincón et al. 2007; Ramírez-García et al. 2012). Therefore, as LAI of the pasture increases, the amount of light that reaches the ground will be reduced, which can prevent or retard weed growth.

Furthermore, it has been reported that SLA in *Brachiaria* cultivars varies according to species; Baruch and Guenni (2007) reported that at 4 weeks of age SLA in *B. decumbens* and *B. brizantha* were 300 and 270 cm^2/g, respectively. Also, it has been reported that, as the height and age of the plant increase, SLA decreases (Gómez et al. 2012), as it did in our study, because there is an increment in the thickness of the leaves. Grasses with greater SLA have thinner leaves and higher concentrations of nitrogen (Pérez et al. 2004) and higher rates of photosynthesis (Reich et al. 1997), while a high SLA is related to greater palatability and consumption by animals (Lloyd et al. 2010; Zheng et al. 2014).

The CP values obtained in this study for Señal were higher than those reported by Alvarado et al. (1990) at 6 and 9 weeks of age (9.4 and 8.8%, respectively), while the values obtained in Mulato II were similar to those found by Castillo et al. (2006) at 3 weeks (15%). The values obtained in Xaraés, Marandú and Piatá were similar during the rainy season to, and higher in the dry season than, those obtained by Pérez et al. (1999) in *B. brizantha* at 6 and 9 weeks (11.9 and 8.6%, respectively). Water deficiency stress can have a negative effect on *Brachiaria* cultivars, decreasing the concentration of CP. In this regard, Cuadrado et al. (2004) reported that at 24 days of regrowth CP concentration in the wet season was higher than in the dry season for Marandú (10.5 vs. 9.3%), Señal (15.4 vs. 9.2%) and Xaraés (11.5 vs. 8.2%). Increasing age of the plant also decreases the concentration of CP in forage because of accumulation of dry matter (resulting in dilution of nutrients), increase in stem DM and decline in the proportion of leaf (Juárez-Hernández et al. 2004; Reyes-Purata et al. 2009), as shown in our study. All cultivars had CP concentrations above 7% which is considered the minimum, below which intake by ruminants could be suppressed (Lazzarini et al. 2009). The choice of cultivar to use could depend on a range of factors including DM yield of leaf, CP concentration, rate of regrowth, response to fertilizer etc.

Conclusions

While the dry season negatively affected the production and nutritional value of forage of all grasses evaluated, the most outstanding cultivars in terms of leaf yield, leaf area index and specific leaf area were: Mulato II, Marandú and Xaraés. Xaraés certainly showed the best tolerance of dry conditions, while performing well in terms of total DM and leaf production in the rainy season. However, Mulato II showed high DM yield and nutritional value over time, which supports its further evaluation in grass production systems in humid tropical conditions, especially as good CP levels (11–14%) were maintained for long periods in both rainy and dry seasons. This was a plot study and plants were only 12 weeks old when observations commenced, but the results do indicate that all cultivars performed well and further evaluation of the more promising cultivars under field conditions, particularly under grazing, is warranted.

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