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Technical note

Forage yield and digestibility of *Urochloa* spp. cultivars at three regrowth ages in the rainy and dry seasons in Ecuador

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Abstract:

The humid tropics of Ecuador is a potential livestock production area. *Urochloa* spp. cultivars are a forage option in this region. Environmental and management conditions determine forage yield and nutritional value and should be researched prior to establishing new forage species. An evaluation was done of total dry matter yield (TDM; t ha^{-1}), morphological components proportions (%; leaf, stem, dead material and inflorescence) and *in situ* dry matter digestibility (DMD; g kg^{-1})) in five *Urochloa* cultivars (Mulato II, Marandú, Xaraés, Piatá and Señal [control]) and at three regrowth ages (4, 6 and 8 wk) during the rainy and dry seasons. A completely randomized block design in a split plot arrangement was used to analyze the data by season. During the rainy season, TDM did not differ (P>0.05) between cultivars. In the dry season, Marandú had a lower yield than Xaraés (0.92 *vs* 1.21 t ha^{-1}). Morphological component proportions differed between cultivars (P<0.05), although the leaves contributed the most overall to yield. From four to eight weeks, DMD decreased from 64 to 56 % in the rainy season and from 60 to 56 % in the dry season. The evaluated cultivars exhibited acceptable TDM yields (2.6 t ha^{-1} in rainy season, 1.0 t ha^{-1} in dry season) and DMD (602 g kg^{-1} in rainy season, 574 g kg^{-1} in dry season). They are adequate forage alternatives for livestock in the humid tropics of Ecuador.

Key words: Hybrid *Brachiaria*, *Brachiaria brizantha*, *Brachiaria decumbens*, Rainy season, Dry season, Morphological composition, Nutritional value.

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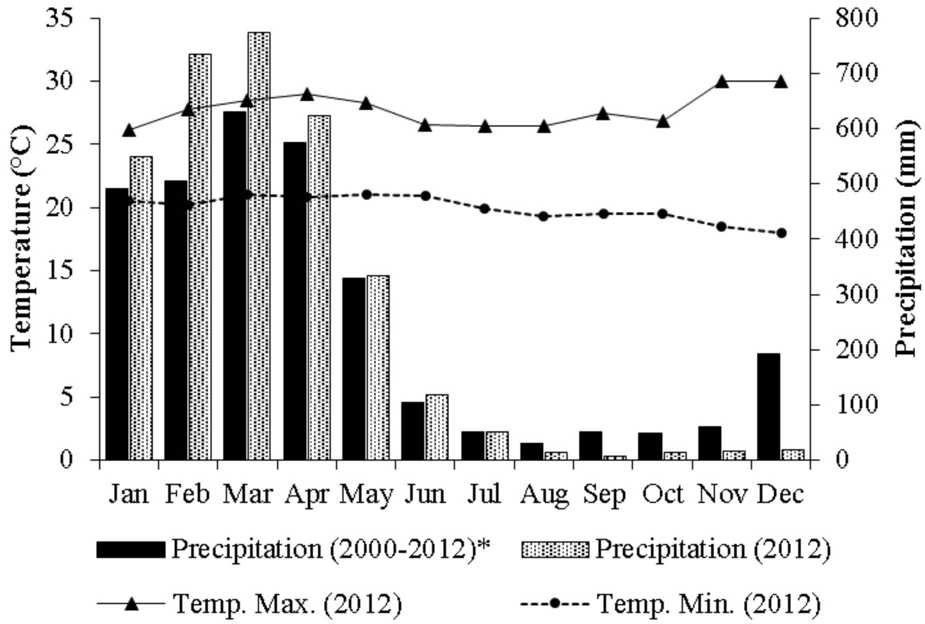
Ruminant livestock systems are based on forage as a low-cost feed source in extensive production systems and as a complement in intensive systems(1). Livestock productivity in the tropical zones of Ecuador is limited by low grassland forage yield. Two *Urochloa* (Syn. *Brachiaria*) species *U. humidicola* and *U. decumbens* dominate grasslands in Ecuador, but have low forage yield and nutritional value. They are also susceptible to the damaging effects of *Aeneolamia* spp. insects and foliar fungi such as *Rhizoctonia solani*, which significantly reduce forage yield(2).

To improve forage quality and increase livestock production, *Urochloa* cultivars have been selected for their adaptation to soils with poor fertility and toxic aluminum levels, resistance to pests and diseases, and higher forage yield and nutritional value(3). Different *Urochloa* cultivars have been introduced to overcome the problems observed in *U. humidicola* and *U. decumbens*(4). For example, annual dry matter (DM) production in *U.* hybrid cv. Mulato II and *U. brizantha* cv. Xaraés ranges from 25 to 30 t ha^{-1}(5,6,7), while in *U. decumbens* the range is from 11 to 19 t ha^{-1}(8). In studies of *U. decumbens*, *U.* hybrid cv. Mulato I and *U. humidicola*(9,10,11), as well as *U. brizantha* cv. Marandú and *U.* hybrid cv. Mulato II(12), total DM production was similar, although differences were observed in morphological composition. In some genotypes (Mulato I and II), higher leaf production correlated with higher crude protein content[13]. The Mulato II hybrid significantly outperforms other commonly used brachiariae (*U. brizantha* and *U. humidicola*) in terms of forage quality due to its 67 % DM digestibility[14]; this is notably higher than the 58% DM digestibility of Xaraés and the 43 % of *U. decumbens*[15].

Genetic composition largely determines a forage species' productive capacity[2], but environmental factors (climatic conditions) and pasture management modify the expression of foraging behavior and forage nutritional value[16,17]. Before introducing a new forage species it is vital to evaluate its agronomic performance under controlled conditions to confirm that it is a viable option for livestock in the region[11]. The present study objective was to evaluate forage yield, morphological composition and *in situ* digestibility of five *Urochloa* spp. forage cultivars at three regrowth ages, during the rainy and dry seasons in the humid tropics of Ecuador.

The study was carried out under seasonal conditions from December 2011 to November 2012. The experimental site is located in the El Oasis Farm of the School of Agricultural Engineering, Santo Domingo Campus, Equinoctial Technological University (Universidad Tecnológica Equinoccial), Ecuador (00° 13' 19.70" S; 79° 15' 39.00" W; 406 m asl). Local soils are classified as Andisol, with a 5.9 pH and 2.2 % organic matter content. The soil mineral profile consists of NH_4 (41.0 mg kg^{-1}), P (6.5 mg kg^{-1}), S (6.3 mg kg^{-1}), Fe (42.0 mg kg^{-1}), K (0.3 cmol kg^{-1}), Ca (8.3 cmol kg^{-1}) and Mg (2.9 cmol kg^{-1}). In the Köppen classification system, regional climate is tropical monsoon (Am), characterized by two well-defined periods or seasons: rainy (January to June) and dry (July to December). This is clearly reflected in the average monthly rainfall and temperatures (maximum and minimum) recorded during the experimental period, and average monthly rainfall from 2000 to 2012 (Figure 1).

Figure 1: Rainfall and temperature during experimental period, and average rainfall from 2000-2012



Two factors were studied: 1) cultivars, *U. brizantha* (Marandú, Piatá and Xaraés), the Mulato II hybrid (*U. ruziziensis* X *U. brizantha*) and *U. decumbens* as a control; and 2) regrowth age, 4, 6 and 8 wk. Harvest of each of the three genotypes was done at each regrowth age during both the rainy (13 March to 12 May, T_{min}=20.8 °C, T_{max}=28.6 °C; accumulated rainfall = 1,733 mm) and dry seasons (7 September to 3 November, T_{min}=19.2 °C, T_{max}=28.1 °C; accumulated rainfall = 39 mm).

Commercial seed was sown on 17 December 2011. Emergence of at least one plant was guaranteed by planting three seeds each in black polyethylene bags (approximate 2 kg) containing soil from the experimental site. Seven weeks after planting (4 February 2012), the plants were transplanted to 5×5 m plots (25 m^2) with 0.5 m between plants and rows (total = 40,000 plants ha^{-1}). Within each plot the effective area was 9 m^2, which encompassed 7, three-meter-long rows containing 7 plants each. Three of the plants in each row were randomly selected for harvest at each regrowth age. At the time of transplanting, all plots were fertilized: 120 kg ha^{-1} N (Urea, FERTISA S.A., Ecuador); 60 kg ha^{-1} P_2O_5 (DAPHOS, Tecnifertpac S.A., Ecuador); 70 kg ha^{-1} K_2O (potassium muriate, FERTISA S.A., Ecuador); 60 kg ha^{-1} Mg (magnesium oxide, Interfilk S.A., Ecuador); and 50 kg ha^{-1} SO_4 (ammonium sulfate, FERTISA S.A., Ecuador).

The rainy season evaluation was begun on 17 March 2012, six weeks after transplanting, by making a uniform cut 15 cm above ground level. At the end of the rainy season, the plots were allowed to recover to avoid overlap between seasons and prevent confounding effects. The dry season evaluation was begun on 7 September 2012, by making a uniform cut 15 cm above ground level. For each sampling (4, 6 and 8 wk in both seasons), all the forage present in the 3 m effective area (i.e. seven plants) was harvested at 15 cm above ground level and weighed on a precision scale (Model PB3002-S, Mettler Toledo®, Switzerland) at the time of cutting (green matter). Samples were dried in a forced-air oven (Model 100-800, Memmert, Germany) at 65 °C for 48 h to estimate dry matter (DM) content. Two subsamples of approximately 0.2 and 1.0 kg were taken. The first was separated into morphological components (leaf, stem, dead material and inflorescence) and the second used for chemical and *in situ* digestibility analysis.

The variables evaluated included total dry matter yield (TDM; t ha^{-1}) and the DM proportion (%) of each morphological component: leaf (DMl), stem (DMs), dead material (DMd) and inflorescence (DMi). Total dry matter (TDM), the neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (Lig) contents (g kg^{-1}) of the TDM were measured with an ANKOM fiber analyzer (ANKOM 200/220®) following ANKOM Technology protocols[(18)]. *In situ* DM digestibility (DMD; g kg^{-1}) was quantified using the technique of Vanzant *et al*[(19)]. For the DMD analysis, samples were ground to a 2 mm particle size and 4 g sample (DM) placed in a 15×7 cm nylon bag (50 ± 10 µm pore size) tied to a metal chain. By means of a ruminal cannula, the samples were incubated for 48 h in three Holstein cows (560 ± 23 kg) feeding in *Lolium perenne* pastures and with free access to water. The samples were removed and washed with running tap water until the effluent became clear. They were dried in a forced-air oven at 65 °C for 48 h and weighed on an analytical scale.

The data were analyzed by season in a completely randomized design with four replicates and a divided plot arrangement; the large plot was cultivar and the small plot was regrowth age. Treatment means were compared with a Tukey test (α=0.05). The statistical analyses were run with the GLM procedure in the SAS program[(20)].

During the rainy season, regrowth age positively influenced forage yield (P<0.05), increasing from 1.14 (4 wk) to 4.23 (8 wk) t DM ha^{-1} per cut. At 4 weeks' regrowth, the Marandú cultivar had the lowest TDM yield (0.79 t ha^{-1})(P<0.05), but at wk 6 and 8 TDM did not differ (P>0.05) between cultivars. As a result, average regrowth age TDM yield (2.64 t ha^{-1}) did not differ (P>0.05) between the evaluated cultivars. During the dry season, the Marandú cultivar had lower (P<0.05) TDM values than the Xaraés cultivar (0.92 *vs* 1.21 t ha^{-1}; Table

1). Overall forage yield decreased 60 % from the rainy season (2.64 t ha^{-1}) to the dry season (1.05 t ha^{-1}).

Table 1: Total dry matter yield (t ha^{-1}) of five *Urochloa* cultivars at three regrowth ages in the rainy (March-May) and dry (September-November) seasons

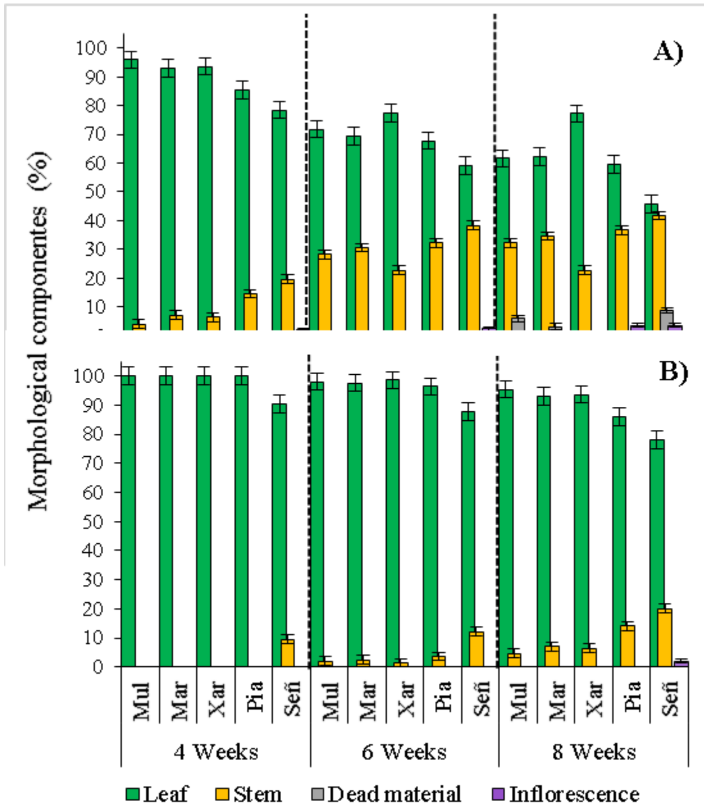
Cultivar	Rainy season								Dry season							
	Regrowth age (weeks)						Average		Regrowth age (weeks)						Average	
	4		6		8				4		6		8			
Señal	0.88	bc	2.71	a	4.22	a	2.60	a	0.41	a	0.77	ab	1.98	ab	1.05	ab
Marandú	0.79	c	2.55	a	3.90	a	2.41	a	0.43	a	0.71	b	1.62	b	0.92	b
Mulato II	1.28	a	2.32	a	4.17	a	2.59	a	0.28	b	0.64	b	1.92	ab	0.95	ab
Piatá	1.16	ab	2.31	a	4.39	a	2.62	a	0.40	ab	0.94	a	1.97	ab	1.10	ab
Xaraés	1.58	a	2.80	a	4.47	a	2.95	a	0.41	a	0.83	ab	2.39	a	1.21	a
Average	1.14	C	2.54	B	4.23	A			0.38	C	0.78	B	1.98	A		

Within each season, different letters in the same column (a, b, c) or the same row (A, B, C) indicate statistical difference (Tukey; P=0.05).

The observed TDM accumulation was similar to that reported in a study of different *U. humidicola* (Rendle) Schweick cultivars during the dry season (average rainfall = 50 mm) in which no differences were found in TDM yield between cultivars[10]. Climate factors such as rainfall and temperature significantly influence forage biomass production[21,22], and yield can drop as much as 50 % during the dry season[23]. This is clearly the case in the present study, in which an approximately1700 mm fluctuation in rainfall resulted in an almost 60 % drop in forage TDM.

Morphological composition varied between genotypes within each season (P<0.05). During the rainy season, Señal grass had the highest DMs proportions among the evaluated regrowth ages. Dead matter (DMd) appeared at eight weeks' regrowth in Señal (9 %), Mulato II (6 %) and Marandú (3 %), but not in the Piatá and Xaraés cultivars. Inflorescence DM (DMi) was only observed in Señal (0.6 % at 4 wk, 1.2 % at 6 wk, 3.5 % at 8 wk) and Piatá (3 % at 8 wk) in this season (Figure 2A).

Figure 2: Proportion of morphological components in five *Urochloa* cultivars at three regrowth ages in the rainy (A) and dry (B) seasons



Mul: Mulato II, Mar: Marandú, Xar: Xaraés, Pia: Piatá, Señ: Señal. Within each regrowth age, the bars represent statistical difference (Tukey, P=0.05).

Differentiation in morphological components between cultivars and regrowth periods was less pronounced during the dry season. At 4 wk the proportion of DMl was lowest in Señal (90 %) since it was the only cultivar to exhibit DMs (10 %) at this age. None of the cultivars had DMd at any time and DMi was only observed in Señal at 8 wk (2%; Figure 2B). In both seasons, DMl made the highest contribution to TDM yield, followed by DMs, DMd and DMi.

Season and regrowth age influenced cultivar DM production and morphological composition. The changes observed during the rainy season are the result of a higher tissue turnover rate and active growth, mainly due to moisture availability[24]. During the dry season growth decreased[9], stem growth was minimal and therefore DMl constituted the greatest contribution to forage yield and caused leaves to be the component that most contributed to TDM yield (Figure 2).

In all the cultivars, DMD during the rainy season only differed ($P<0.05$) between four and six weeks' regrowth (Table 2). In the dry season, by contrast, differences ($P<0.05$) in DMD were observed between six and eight weeks' regrowth. The overall decrease in DMD from four to eight weeks was 15.9 % (86 g kg^{-1}) in the rainy season and 5.7 % (34 g kg^{-1}) in the dry season. Similar behavior has been reported in *U. decumbens*, Marandú and Xaraés, in which average DMD was higher during the rainy season (650 *vs* 620 g kg^{-1})[21]. This discrepancy between seasons might be due to higher production of secondary metabolites (phenylpropanoid conjugates with amines) during the dry season when plants are under stress; these are incorporated into the plant cell wall to increase its rigidity[25,26], consequently decreasing DMD.

Table 2: *In situ* dry matter digestibility (g kg^{-1}) of five *Urochloa* cultivars at three regrowth ages during the rainy and dry seasons

Cultivar	Rainy season								Dry season							
	Regrowth age (weeks)						Average		Regrowth age (weeks)						Average	
	4		6		8				4		6		8			
Señal	638	ab	581	b	533	a	584	b	598	a	549	b	553	ab	567	bc
Marandú	670	a	621	ab	576	a	622	a	609	a	598	a	609	a	605	a
Mulato II	649	ab	646	a	580	a	625	a	590	a	571	ab	563	a	574	b
Piatá	647	ab	586	b	565	a	599	ab	595	a	557	b	584	a	579	b
Xaraés	615	b	589	b	533	a	579	b	588	a	541	b	500	b	543	c
Promedio	644	A	604	B	558	C			596	A	563	B	562	B		

Within each season, different letters in the same column (a, b, c) or same row (A, B, C) indicate statistical significance (Tukey; α=0.05).

In situ dry matter digestibility (DMD) was >540 g kg^{-1} in all genotypes, regardless of season. It was highest in Mulato II and Marandú and lowest in Señal (*U. decumbens*). These results coincide with an another study in which *U. decumbens* was found to have lower digestibility than *U. brizantha* (430 vs. 580 g kg^{-1})[15]. This discrepancy may arise from the fact that *U. brizantha* develops fibers with lower lignin content and thinner cell walls than *U. decumbens*[27]. The observed progressive decrease in DMD with regrowth period is mainly due to plant maturation and the consequent increase in lignin bound to hemicellulose and cellulose[28], which lowers rumen microorganism effectiveness and may reduce forage digestibility[29].

Neutral detergent fiber (NDF), ADF and Lig differed by season (P<0.05) between cultivars and regrowth ages (Table 3). During the rainy season, Xaraés had the highest NDF, ADF and Lig contents (P<0.05). During the dry season, Señal had 25% more Lig (P<0.05) than Mulato II (79 vs. 63 g kg^{-1}). In both seasons, fiber content (NDF and ADF) increased in response to regrowth age from four to eight weeks. In the rainy season, NDF increased (P<0.05) by 3.7 % (25 g kg^{-1}), ADF by 6.1 % (24 g kg^{-1}) and Lig by 30.7 % (17 g kg^{-1}), while in the dry season NDF increased (P<0.05) by 4.8 % (32 g kg^{-1}), ADF by 12.3 % (44 g kg^{-1}) and Lig by 26.9 % (17 g kg^{-1}). This increase in cell wall components and consequent reduction in DMD was probably due to plant maturity[16] and the intrinsic characteristics of each genotype[2,30].

Table 3: Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (Lig) contents in five *Urochloa* cultivars, at three regrowth ages during the rainy and dry seasons

Cultivar	Rainy season								Dry season							
	Regrowth age (weeks)						Average		Regrowth age (weeks)						Average	
	4		6		8				4		6		8			
NDF (g kg^{-1})																
Señal	659	ab	681	a	691	b	677	c	646	ab	670	a	696	a	671	a
Marandú	669	ab	683	a	692	b	682	bc	656	ab	678	a	691	ab	675	a
Mulato II	649	b	660	a	660	c	656	d	619	b	661	a	669	b	650	b
Piatá	678	ab	683	a	712	a	691	ab	682	a	686	a	696	a	688	a
Xaraés	694	a	693	a	718	a	702	a	685	a	680	a	696	a	687	a
Average	670	B	680	B	695	A			658	C	675	B	690	A		
ADF (g kg^{-1})																
Señal	387	b	381	b	409	bc	392	b	352	b	394	a	414	a	387	bc
Marandú	399	b	397	ab	410	b	402	b	346	bc	391	a	402	ab	380	c
Mulato II	360	c	375	b	388	c	375	c	331	c	374	b	380	b	361	d
Piatá	395	b	388	ab	427	ab	403	b	379	a	393	a	399	ab	390	ab
Xaraés	417	a	422	a	445	a	428	a	377	a	403	a	411	a	397	a

Average	392	B	393	B	416	A			357	C	391	B	401	A		
Lig (g kg^{-1})																
Señal	70	a	77	b	92	b	80	b	68	a	77	a	91	a	79	a
Marandú	64	a	69	cd	78	c	70	cd	62	a	67	a	84	ab	71	ab
Mulato II	61	a	62	d	71	c	64	d	57	a	63	a	69	c	63	b
Piatá	63	a	70	bc	83	b	72	bc	63	a	68	a	79	bc	70	ab
Xaraés	70	a	91	a	103	a	88	a	64	a	68	a	78	bc	70	ab
Average	65	C	74	B	85	A			63	C	69	B	80	A		

Within each season, different letters in the same column (a, b, c, d) or the same row (A, B, C) indicate significant difference (Tukey; α=0.05).

The NDF and ADF contents observed here at six weeks in both seasons (rainy and dry) are similar to those reported previously at 40 days' regrowth for three cultivars: Marandú (680 and 396 g kg^{-1}), Xaraés (700 and 400 g kg^{-1}) and Piatá (670 and 370 g kg^{-1})[(31)]. However, the present Lig values are higher than those reported in the same previous study at 40 days' regrowth for Marandú (45 g kg^{-1}) and Piatá (43 g kg^{-1})[(31)]. Both season and regrowth age affect cell wall components; for example, at 24 days' regrowth NDF was lower during the rainy season than in the dry season in *U. decumbens* (610 *vs* 690 g kg^{-1}) and *U. brizantha* cv. Xaraés (690 *vs* 710 g kg^{-1}), as was ADF (*U. decumbens*, 230 *vs* 340 g kg^{-1}; and *U. brizantha* cv. Xaraés, 430 *vs* 510 g kg^{-1})[(21)]. Cultivar can also affect these variables; in the present results, during the rainy season the Xaraés cultivar had the highest NDF, ADF and lignin contents, and lowest DMD, while the Mulato II cultivar had the lowest values for these cell wall components and the highest DMD. Lignin interferes with the use of digestible energy and is considered an antinutritional component[(29)]. This is because in grasses, unlike in legumes, a greater proportion of lignin is bound to hemicellulose and cellulose[(32)], which prevents microbial action, lowering forage digestibility[(28)]. Lignin content can also increase when plants experience stress due to high temperatures. They protect themselves through the structural mechanism of increasing cell walls (which are mainly lignin), thus reducing forage digestibility[(25)].

Lack of precipitation during the dry season negatively affected all the evaluated variables. Regrowth age significantly affected yield, morphological composition, fiber content and *in situ* dry matter digestibility. All the cultivars exhibited acceptable dry matter production per cut in both seasons even though the grasslands were recently established. The *in situ* digestibility values in the Mulato II and Marandú cultivars remained constant over time. Forage availability is critical in the humid tropics of Ecuador, especially at the end of the dry season. The present results suggest the Mulato II, Marandú and Xaraés cultivars are promising forage alternatives due to their dry matter content and digestibility.

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