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Research Paper

Herbage yield and quality of 12 *Urochloa* cultivars and lines in Northeast Thailand

Rendimiento y calidad de forraje de 12 cultivares y líneas de Urochloa *en el noreste de Tailandia*

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Abstract

Forage accumulation yields and nutritive value of 12 *Urochloa* cultivars and pre-commercial lines (Mulato II, Cayman, Cobra, Marandu, Toledo, BRS Piatã, BRS Paiaguás, Ruzi, Humidicola, BRO4/3025, BRO4/3207 and BRO4/2515) were evaluated in a field trial in Northeast Thailand during 2015–2018. Total herbage yields for cultivars and lines over 3 years ranged from 15,800 kg DM/ha (Ruzi) to 33,800 kg DM/ha (Toledo). Toledo produced the highest total biomass across the 3 wet and dry seasons. BRS Piatã and BRS Paiaguás showed good performance, out-yielding Ruzi and Mulato II in total DM in both wet and dry seasons. The 6 hybrid *Urochloa* cultivars/lines (Mulato II, Cayman, Cobra, BRO4/3025, BRO4/3207 and BRO4/2515) all accumulated similar total DM yields over 3 years, outyielding Ruzi ($P<0.05$). Crude protein concentrations in forage were higher ($P<0.05$) in the dry season than wet season and in leaf than stem. In the second and third dry seasons, Ruzi had higher CP concentrations in both leaf and stem than all other cultivars and lines. ADF and NDF concentrations were lower in the dry season than the wet season. This trial has shown that BRS Piatá and BRS Paiaguãs would be ideal replacements for Mulato II and Ruzi in Northeast Thailand because of their superior dry season production for smallholder farmers for either cut-and-carry forage or grazing.

Keywords: acid detergent fiber, crude protein, dry matter yield, neutral detergent fiber.

Resumen

Se evaluaron los rendimientos de acumulación de forraje y el valor nutritivo de 12 cultivares y líneas pre-comerciales de *Urochloa* (Mulato II, Cayman, Cobra, Marandu, Toledo, BRS Piatã, BRS Paiaguás, Ruzi, Humidicola, BRO4/3025, BRO4/3207 y BRO4/2515) en un ensayo de campo en el noreste de Tailandia durante 2015–2018. Los rendimientos totales de forraje de los cultivares y líneas durante 3 años oscilaron entre 15,800 kg de MS/ha (Ruzi) y 33,800 kg de MS/ha (Toledo). Toledo produjo la mayor biomasa total en las 3 temporadas húmedas y secas. BRS Piatã y BRS Paiaguás tuvieron un buen desempeño, superando a Ruzi y Mulato II en MS total en ambas épocas (húmeda y seca). Los 6 cultivares/líneas híbridas de *Urochloa* (Mulato II, Cayman, Cobra, BRO4/3025, BRO4/3207 y BRO4/2515) acumularon rendimientos totales de MS similares durante 3 años, superando a Ruzi ($P<0.05$). Las concentraciones de proteína cruda en el forraje fueron más altas ($P<0.05$) en la temporada seca que en la húmeda y en la hoja que en el tallo. En la segunda y tercera temporadas secas, Ruzi tuvo concentraciones de PC más altas tanto en hojas como tallos que todos los demás cultivares y líneas. Las concentraciones de FDN y FDA fueron más bajas en la temporada seca que en la húmeda. Este ensayo ha demostrado que BRS Piatá y BRS Paiaguãs serían ideales como reemplazo de Mulato II y Ruzi en el noreste de Tailandia debido a su producción superior en la temporada seca para los pequeños agricultores, ya sea para forraje de corte y acarreo o para pastoreo.

Palabras clave: fibra detergente ácida, fibra detergente neutra, proteína cruda, rendimiento de materia seca.

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Introduction

Urochloa (formerly *Bracharia*) species are the second most common pasture grasses grown in Thailand after *Megathyrsus maximus* cultivars (Hare 2020). *U. ruziziensis* is grown widely in Thailand because of the availability of large quantities of relatively cheap seed (US$4–6/kg), although its dry season production is very low (1,000–2,000 kg dry matter (DM)/ha) (Hare et al. 2005; 2009). Several new cultivars and pre-commercial lines of *Urochloa* have been produced, which could be suitable for sowing in Thailand (Table 1). Among them, *Urochloa* hybrid Mulato II is now increasing rapidly in popularity, because of its superior dry season production (3,000–4,000 kg DM/ha), high leaf production (77–90 % leaf) and high nutritive value (Hare et al. 2009; 2015a), despite its relatively high seed price (US$12–14/kg).

Several field trials in Thailand over time have examined production and quality of a range of *Urochloa* hybrids and species compared with Mulato II (Hare et al. 2005; 2009; 2013; 2015a) and found inconsistent differences in production between Mulato II and the other *Urochloa* grasses. For example, Cayman produced more total DM than Mulato II in only one wet season and one dry season, with significantly lower leaf production (Hare et al. 2013; 2015a). Cobra had similar DM production to Mulato II, but with lower leaf production (Hare et al. 2015a). Toledo produced higher wet and dry season DM yields than Mulato II in one series of trials (Hare et al. 2009), but in another series of trials, DM yields of Toledo were similar to or lower than those of Mulato II (Hare et al. 2009; 2015a). DM yields of Marandu were similar to those of Mulato II in the wet season, but lower than those of Mulato II in the dry season (Hare et al. 2009). In all trials, Mulato II consistently produced the highest percentage of leaf compared with other *Urochloa* cultivars and lines.

BRS Piatã and BRS Paiaguás were reported to have high DM production during the dry season in Brazil (Euclides et al. 2001, 2009; Valle et al. 2013). These cultivars are potential alternatives to existing *Urochloa* grasses for sowing in Thailand. In addition, 3 new *Urochloa* hybrid pre-commercial lines from Brazil (BRO4/3025, BRO4/3207 and BRO4/2515) selected for good drought tolerance and Humidicola were made available from Tropical Seeds LLC.

The objective of this research was to examine the seasonal production and quality in a field trial over 3 years of 2 *U. brizantha* grasses (BRS Piatã and BRS Paiaguás), 3 *Urochloa* hybrid lines (BRO4/3025, BRO4/3207 and BRO4/2515) and *U. humidicola* cultivar 'Humidicola', all new to Thailand, in comparison with Mulato II, Cayman, Cobra, Marandu, Toledo and Ruzi. We hypothesized that some of the new cultivars/lines would be superior to the existing cultivars, especially during the dry season.

Table 1. Background of cultivars/pre-commercial lines of *Urochloa* species and hybrids.

Name	Species and full name	Synonyms	Country and year of cultivar registration
Marandu	*U. brizantha* (Hochst. ex A. Rich.) R.D. Webster cultivar 'Marandu'	BRA 000591	Brazil 1984
Toledo	*U. brizantha* cultivar 'Toledo'	CIAT 26110, Xaraés (Kenya & Brazil)	Costa Rica 2000
BRS Paiaguás	*U. brizantha* cultivar 'BRS Paiaguás'	BRA 003891	Brazil 2013
BRS Piatã	*U. brizantha* cultivar 'BRS Piatã'	BRA 002844	Brazil 2007
Ruzi	*U. ruziziensis* (R. Germ. & C. M. Evrard) Crins	CPI 30623, CIAT 605, BRA 000281, ILRI 16692	Australia 1966
Cayman	*U. ruziziensis* × *U. decumbens* (Stapf) R. D. Webster × *U. brizantha* cultivar 'Cayman'	CIAT BR02/1752	Mexico, Guatemala, Honduras and USA 2011
Mulato II	*U. ruziziensis* × *U. decumbens* × *U. brizantha* cultivar 'Mulato II'	CIAT 36087, Convert Brazil	Colombia and Mexico 2005
Cobra	*U. ruziziensis* × *U. decumbens* × *U. brizantha* cultivar 'Cobra'	CIAT BR02/1794	Mexico and Argentina 2013
Humidicola	*U. humidicola* (Rendle) Morrone & Zuloaga cultivar 'Humidicola'		Panama 1990
BRO4/3025	*U. ruziziensis* × *U. decumbens* × *U. brizantha*	Camello	Mexico 2019
BRO4/3207	*U. ruziziensis* × *U. decumbens* × *U. brizantha*		
BRO4/2515	*U. ruziziensis* × *U. decumbens* × *U. brizantha*		

Materials and Methods

A field experiment was conducted at Ubon Ratchathani University, Thailand, (15°14'38" N, 104°50'55" E; 130 masl) from 2015 to 2018. The site was an upland sandy low humic gley (Paleaquult) soil (Roi-et series) (Mitsuchi et al. 1986). Soil samples, taken at seed sowing in July 2015, showed that the soil was acidic (pH 4.4; water method) and low in organic matter (0.7 %), N (0.03 %), P (8.9 ppm; Bray II extraction method) and K (7.1 ppm; Flame Photometer method). During the 5 years prior to the commencement of the experiment, the site was used for a series of *Megathyrsus* grass trials. The site was prepared and 12 *Urochloa* grass cultivars and pre-commercial lines (Table 1) were sown in 3 × 5 m plots in a randomized complete block design with 4 replications. Details of field crop management are presented in Table 2.

Seed germination laboratory tests (alternating temperatures of 12 h light at 35 ºC and 12 h dark at 25 ºC) prior to sowing indicated percentage germination of Mulato II 50 %, Cayman 50 %, Cobra 50 %, Marandu 30 %, Toledo 30 %, BRS Piatã 10 %, BRS Paiaguás 28 %, Ruzi 30 %, Humidicola 50 %, BRO4/3025 50 %, BRO4/3207 50 % and BRO4/2515 50 %. Sowing rates were adjusted to 10 kg pure-live-seed/ha. At each sampling cut (Table 2), when the grasses were at about 40–60 cm above ground level, herbage in six 0.25 m^2 quadrats per plot was cut at 5 cm from ground level and weighed fresh. A 300 g subsample, taken from the bulked sample, was divided into leaf and stem and subsamples dried separately at 70 °C for 48 h to determine dry weight. Dry weight data were accumulated each season to give total dry matter, stem and leaf yields for each season. The dried subsamples were bulked for each season and analyzed for total N using the Kjeldahl method (Kjeldahl 1883) and crude protein (CP) estimated (CP, % N × 6.25). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations were measured from seasonal bulked subsamples using the Van Soest method (Van Soest 1963). At each sampling cut, observations were recorded for emergence of inflorescences. After each sampling cut, remaining herbage in the plots was cut to 5 cm from ground level and removed.

Data from the experiments were subjected to analysis of variance, using the IRRISTAT program from the International Rice Research Institute (IRRI). Means of variables were compared using Fisher's protected LSD (P≤0.05).

Results

Rainfall

Rainfall during the wet season (May–Oct) in 2016 and 2017 was 18 and 10 %, respectively, above the 20-yr mean (Figure 1). In the dry season (Nov-Apr) rainfall was close to average in the 2015/2016 season, 13 % below average in the 2016/2017 season and 26 % above average in the 2017/2018 season.

Forage accumulation and feed quality

For all cultivars and lines, as expected DM production during the wet seasons (Table 3) far exceeded that in the dry seasons. Over 3 wet seasons, Toledo accumulated 31, 41, 44, 83 and 111 % more total DM than BRS

Table 2. Field crop management during the evaluation of *Urochloa* cultivars and lines.

Management (time)	Activity
Spraying (Jun 2015)	Glyphosate at 3 L/ha
Field cultivation (Jul 2015)	Plowing × 2, disking × 1, harrowing × 1
Sowing method (10 Jul 2015)	Seed hand-broadcast and raked into soil along with lime and NPK fertilizer
Sowing rate adjusted for germination	10 kg pure-live-seed/ha
Fertilizer	1,000 kg lime/ha and 200 kg NPK/ha (15:15:15) at sowing; 200 kg NPK/ha (15:15:15) after each sampling harvest
Sampling harvests	
First wet season (2015)	17 Sep, 2 Nov (Two cuts as seed was sown in mid-wet season)
First dry season (2016)	25 Apr
Second wet season (2016)	9 Jun, 25 Jul, 6 Sep, 25 Oct
Second dry season (2017)	17 Jan, 25 Apr (Two cuts due to good growth in Nov and Dec)
Third wet season (2017)	6 Jun, 19 Jul, 4 Sep, 16 Oct
Third dry season (2018)	1 May

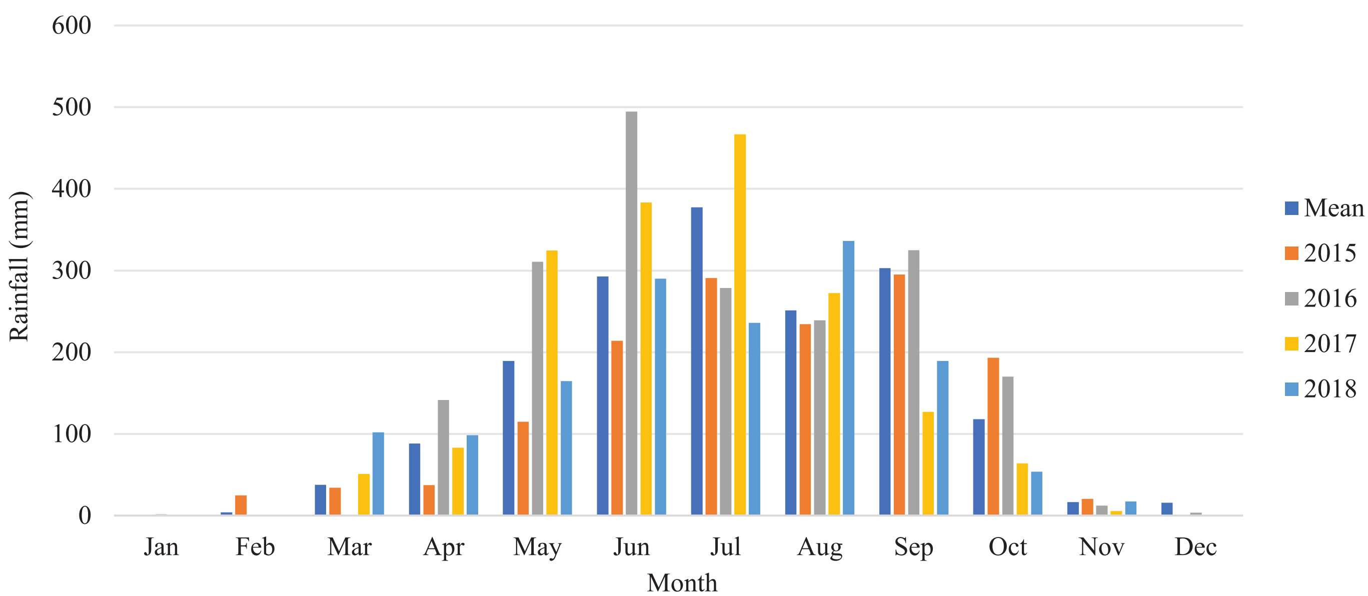

Figure 1. Rainfall at the Ubon Ratchathani University meteorological station, 200 m from the research site, during the experiment compared with the medium-term mean (1998–2018).

Table 3. Total dry matter accumulation (kg/ha) of *Urochloa* cultivars and lines in wet (May–Oct) and dry (Nov–Apr) seasons during 2015 to 2018 at Ubon Ratchathani, Thailand.

Cultivar/line	First year 2015–2016		Second year 2016–2017		Third year 2017–2018		Accumulated total yield	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mulato II	3,372bc[1]	426b	9,508bc	1,630b	8,024bc	1,160b	20,904bc	3,216b
Cayman	6,016a	483bc	9,440bc	2,014ab	8,580bc	1,088b	24,036ab	3,585ab
Cobra	5,887a	457b	8,164c	1,572b	6,336c	1,013bc	20,387bc	3,042b
Marandu	5,982a	465b	10,152b	1,778b	8,836b	1,126b	24,970ab	3,369ab
Toledo	4,778ab	481b	12,408ab	2,360ab	12,336a	1,426ab	29,522a	4,267ab
BRS Piatã	3,036bc	602a	13,184a	2,194ab	10,020b	1,527a	26,240b	4,323a
BRS Paiaguás	2,741bc	571ab	9,844bc	2,616a	9,900b	1,263ab	22,485b	4,450a
Ruzi	4,670ab	520ab	6,312c	640c	5,412c	697c	13,983c	1,857c
Humidicola	1,759c	418b	7,412c	2,640a	6,920c	1,095b	16,091c	4,153ab
BRO4/3025	5,132ab	558ab	10,108b	1,926b	8,940b	1,297ab	24,180ab	3,781ab
BRO4/3207	4,499ab	521ab	10,604b	2,120ab	9,704b	1,384ab	24,807ab	4,025ab
BRO4/2515	5,867a	514ab	9,892bc	2,386ab	9,804b	1,379ab	25,563ab	4,279ab
LSD (P<0.05)	2,054	107	1,900	644	1,848	332	5,802	1,083

[1]Means within columns followed by the same letter are not significantly different (P>0.05).

Paiaguás, Mulato II, Cobra, Humidicola and Ruzi, respectively (P<0.05; Table 3). The 6 *Urochloa* hybrids (Mulato II, Cayman, Cobra, BRO4/3025, BRO4/3207 and BRO4/2515), Marandu, BRS Piatã and BRS Paiaguás accumulated similar DM yields over the 3 wet seasons and significantly (P<0.05) more DM than Ruzi and Humidicola, although BRS Piatã accumulated 28 % more DM over 3 wet seasons than Cobra. In the establishment year, Cayman, Cobra, Marandu and BRO4/2515 out-yielded Mulato II, BRS Piatã, BRS Paiaguás and Humidicola during the wet season (P<0.05; Table 3), while in the first dry season, BRS Piatã (600 kg DM/ ha) produced higher DM yields (P<0.05) than Mulato II, Cayman, Cobra, Marandu and Toledo. Overall yields more than doubled in the second wet season (mean yield 4,478 kg DM/ha in 2015 vs. 9,952 kg DM/ha in 2016) and BRS Piatã (13,000 kg DM/ha) out-yielded all other cultivars and lines (P<0.05), except for Toledo, while Ruzi (6,300 kg DM/ha) had significantly (P<0.05) lower yields than the other cultivars, except for Cobra and Humidicola.

Growth differences between cultivars and lines occurred in the second dry season, when growth far exceeded that in the first dry season, with BRS Paiaguás, Humidicola, Toledo and BRO4/2515 having higher yields (P<0.05) than Mulato II, Cobra and Ruzi. High DM yields persisted in the third wet season (mean 8,734 kg DM/ha), with Toledo (12,300 kg DM/ha) out-yielding all other cultivars and lines, while BRS Piatã and BRS Paiaguás out-yielded Mulato II, Cobra, Ruzi and Humidicola. During the third dry season, DM yields for BRS Piatã (1,500 kg DM/ha) exceeded those for Mulato II, Cayman, Cobra, Marandu, Ruzi and Humidicola (P<0.05).

Overall DM yields for the various cultivars and lines over the 3 years ranged from 15,840 kg/ha for Ruzi to 33,789 kg/ha for Toledo. Accumulated DM yields for Ruzi were significantly lower than for all other cultivars and lines except for Humidicola in the wet season (Table 3).

In the first wet season, Cayman and Marandu produced more leaf DM (3,700 kg leaf DM/ha) than Mulato II, BRS Piatã, BRS Paiaguás, Ruzi, Humidicola and BRO4/3207 (P<0.05; Table 4). In the second wet season, both Toledo (8,400 kg leaf DM/ha) and BRS Piatã (7,900 kg leaf DM/ha) accumulated more leaf DM/ha than all other cultivars (P<0.05). Mulato II and Marandu produced more leaf DM (6,700 kg leaf DM/ha) in the second wet season than Ruzi, Humidicola, BRS Paiaguás, BRO4/3025, BRO4/3207 and BRO4/2515. Similarly in the third wet season, Toledo produced more leaf dry matter (8,500 kg leaf DM/ha) than all other cultivars and lines (P<0.05) and in the same season, Mulato II produced more leaf DM (6,000 kg leaf DM/ha) than Cobra, Ruzi, Humidicola, BRO4/3025, BRO4/3207 and BRO4/2515. Differences between cultivars and lines in leaf production during the dry seasons when yields were low tended to be relatively small, with Toledo consistently the highest and Ruzi the lowest.

In the first wet season, Cobra (2,700 kg stem DM/ha) and BRO4/2515 (2,600 kg stem DM/ha) produced more stem than Mulato II, Toledo, BRS Piatã, BRS Paiaguás and Humidicola (P<0.05; Table 5). In the second wet season, BRS Piatã (5,300 kg stem DM/ha) and BRO4/3207 (5,000 kg stem DM/ha) produced more stem DM than Mulato II, Cayman, Cobra, Marandu, Toledo, BRS Paiaguás, Ruzi and Humidicola (P<0.05; Table 4). In the third wet season BRO4/2515 (5,200 kg stem DM/ha) produced similar stem DM yields to BRO4/3207 and BRO4/3015 and more stem DM than all the other cultivars and lines (P<0.05; Table 5).

In the second dry season Humidicola produced 2–4 times more stem DM (1,260 kg stem DM/ha) than all other cultivars and lines. In contrast, in the third dry season, BRO4/3025, BRO4/2515, BRO4/3207, Humidicola, BRS Paiaguás and BRS Piatã produced similar stem DM yields (320–380 kg stem DM/ha; P>0.05), which were greater than those of Mulato II, Cayman, Cobra, Marandu, Toledo and Ruzi (P<0.05; Table 5).

Mulato II produced a higher proportion (P<0.05) of leaves than all other cultivars and lines in all seasons (wet season average 72 %; dry season average 90 %), except in the first wet season, when Toledo and BRS

Table 4. Total leaf accumulation (kg DM/ha) of *Urochloa* cultivars and lines in wet (May–Oct) and dry (Nov–Apr) seasons from 2015 to 2018 in Ubon Ratchathani, Thailand.

Cultivar/line	First year 2015–2016		Second year 2016–2017		Third year 2017–2018	
	Wet	Dry[1]	Wet	Dry	Wet	Dry
Mulato II	2,306bc[2]	-	6,744b	1,482ab	6,004b	1,033ab
Cayman	3,722a	-	6,000bc	1,654ab	5,492bc	918b
Cobra	3,100ab	-	4,644c	1,254b	3,832cd	804b
Marandu	3,692a	-	6,652bc	1,536ab	5,916bc	922b
Toledo	3,316ab	-	8,432a	1,988a	8,560a	1,202a
BRS Piatã	1,852bc	-	7,884a	1,774ab	6,112b	1,189a
BRS Paiaguás	1,750bc	-	5,828bc	1,840ab	5,836bc	881b
Ruzi	2,259b	-	3,184d	512c	2,800d	502c
Humidicola	913c	-	3,484d	1,374b	3,188d	728bc
BRO4/3025	3,009ab	-	5,454c	1,466b	4,476c	973ab
BRO4/3207	2,580bc	-	5,596c	1,576ab	4,884c	1,039ab
BRO4/2515	3,232ab	-	5,152c	1,762ab	4,564c	995ab
LSD (P<0.05)	1,096	-	1,064	506	1,056	265

[1]Not measured; [2]Means within columns followed by the same letter are not significantly different (P>0.05).

Table 5. Total stem accumulation (kg DM/ha) of *Urochloa* cultivars and lines in wet (May–Oct) and dry (Nov–Apr) seasons from 2015 to 2018 in Ubon Ratchathani, Thailand.

Cultivar/line	First year 2015–2016		Second year 2016–2017		Third year 2017–2018	
	Wet	Dry[1]	Wet	Dry	Wet	Dry
Mulato II	1,066b[2]	-	2,764c	148d	2,020d	127c
Cayman	2,294ab	-	3,440bc	360cd	3,088c	170bc
Cobra	2,787a	-	3,520bc	318cd	2,504cd	209bc
Marandu	2,290ab	-	3,500bc	242c	2,920c	204bc
Toledo	1,462b	-	3,976b	372cd	3,776bc	224b
BRS Piatã	1,184b	-	5,300a	420c	3,908bc	338a
BRS Paiaguás	991b	-	4,016b	776b	4,064b	382a
Ruzi	2,411ab	-	3,128b	128d	2,612cd	195bc
Humidicola	846b	-	3,928b	1,266a	3,732bc	367a
BRO4/3025	2,123ab	-	4,654ab	460c	4,464ab	324a
BRO4/3207	1,919ab	-	5,008a	544bc	4,820ab	345a
BRO4/2515	2,635a	-	4,740ab	624bc	5,240a	384a
LSD (P<0.05)	1,040		908	270	868	94

[1]Not measured; [2]Means within columns followed by the same letter are not significantly different (P>0.05).

Paiaguás had similar leaf proportions to Mulato II (P>0.05; Table 6). Leaf proportions of all cultivars and lines were higher in the dry season than in the wet season. BRO4/3025, BRO4/3207 and BRO4/2515 produced a dense population of inflorescences in September in the first year and in July and September in the second and third years, but inflorescence emergence of other species and lines was negligible.

Indices used to compare feed value of the grasses varied between sampling period (wet vs dry seasons) and cultivar/line. Crude protein concentrations in forage were higher in the dry season than in the wet season and in leaf than in stem (Table 7). Humidicola had higher CP concentrations in both stem and leaf in the first wet season than all other cultivars and lines (P<0.05). In the second and third dry seasons, Ruzi, the other low-yielding grass, had higher CP concentrations in both leaf and stem than all other cultivars and lines. In the second wet season, BRS Piatã had higher CP concentrations in leaf than other cultivars and lines, except for BRS Paiaguás, Ruzi and

Table 6. Leaf proportion (% DM) of *Urochloa* cultivars and lines in wet (May–Oct) and dry (Nov–Apr) seasons from 2015 to 2018 in Ubon Ratchathani, Thailand.

Cultivar/line	First year 2015–2016		Second year 2016–2017		Third year 2017–2018	
	Wet	Dry[1]	Wet	Dry	Wet	Dry
Mulato II	68a[2]	-	73a	92a	75a	89a
Cayman	62b	-	64d	83bc	64cd	84b
Cobra	52c	-	58f	82bcd	62d	79c
Marandu	62b	-	67c	87ab	67c	82bc
Toledo	69a	-	70b	84b	71b	84b
BRS Piatã	61b	-	61e	81b	62de	78c
BRS Paiaguás	64ab	-	61e	71c	60d	70de
Ruzi	48d	-	53g	83bc	54e	73d
Humidicola	52c	-	48h	59d	47f	66e
BRO4/3025	59bc	-	56f	77c	51ef	76cd
BRO4/3207	57bc	-	54g	76c	53e	75cd
BRO4/2515	55c	-	5g	75c	49f	72d
LSD (P<0.05)	5.3	-	2.5	6.6	3.2	4.2

[1]Not measured; [2]Means within columns followed by the same letter are not significantly different (P>0.05).

Humidicola, which had similar CP concentrations. In the third wet season, CP concentrations in leaf of Cobra were similar to those in leaf of Mulato II, Cayman and Ruzi, but higher than for all other cultivars and lines.

ADF (26–50 %) and NDF (45–78 %) concentrations varied between cultivars and lines, seasons and plant parts (Tables 8 and 9). Dry season concentrations were lower than those in the wet season and leaf concentrations were lower than in stems. In most wet seasons, Mulato II, Cayman, Cobra and Ruzi had lower leaf ADF and NDF concentrations than many of the other cultivars and lines (P<0.05; Tables 8 and 9).

Table 7. Crude protein concentrations (%) in stem and leaf of *Urochloa* cultivars and lines in wet (May–Oct) and dry (Nov–Apr) seasons from 2015 to 2018 in Ubon Ratchathani, Thailand.

Cultivar/line	First year 2015–2016				Second year 2016–2017				Third year 2017–2018			
	Wet		Dry[1]		Wet		Dry		Wet		Dry	
	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf
Mulato II	7.7b[2]	13.1b	-	-	2.9ab	7.5b	7.3d	9.6bc	5.9ab	9.2ab	9.9de	12.6b
Cayman	6.1cd	11.1c	-	-	2.1bc	7.3c	7.9c	8.1de	5.4b	9.3ab	12.0c	13.1b
Cobra	5.9cd	11.1c	-	-	1.8c	7.5b	8.6b	8.1de	5.7ab	9.4a	13.2b	12.1bc
Marandu	5.6d	11.0c	-	-	1.7c	7.2b	7.2d	8.9cd	5.5ab	8.3b	8.9ef	12.2bc
Toledo	5.8cd	9.6d	-	-	1.9c	6.3c	7.3d	8.6d	4.9b	8.0b	10.9d	13.2b
BRS Piatã	7.2bc	10.8cd	-	-	1.7c	8.4a	7.3d	7.9e	4.9b	7.2c	10.9d	12.1bc
BRS Paiaguás	7.7b	9.8d	-	-	1.6c	7.8ab	6.2e	7.9e	4.4c	8.2b	10.9d	12.5b
Ruzi	6.6c	11.7c	-	-	3.0ab	7.9ab	12.3a	14.6a	5.9ab	9.2ab	15.9a	17.7a
Humidicola	10.0a	14.3a	-	-	3.3a	7.8ab	5.8e	7.5e	6.0a	8.3b	8.1f	8.9c
BRO4/3025	5.7d	10.8cd	-	-	2.8ab	7.0b	7.8c	9.2cd	5.8ab	8.6b	10.4de	12.2bc
BRO4/3207	5.9cd	10.9cd	-	-	2.4bc	7.2b	7.1d	10.1b	5.8ab	8.1b	9.4e	12.9b
BRO4/2515	6.1cd	11.7c	-	-	2.6b	7.4b	7.5c	9.3c	4.9bc	8.0b	10.8d	13.2b
LSD (P<0.05)	0.8	0.9	-	-	0.5	0.6	0.4	0.6	0.5	0.7	1.0	3.4

[1]Not measured; [2]Means within columns followed by the same letter are not significantly different (P>0.05).

Table 8. Acid detergent fiber concentrations (%) in stems and leaves of *Urochloa* cultivars and lines in wet (May–Oct) and dry (Nov–Apr) seasons from 2015 to 2018 in Ubon Ratchathani, Thailand.

Cultivar/line	First year 2015–2016				Second year 2016–2017				Third year 2017–2018			
	Wet		Dry[1]		Wet		Dry		Wet		Dry	
	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf
Mulato II	26.8b[2]	28.6e	-	-	39.0e	31.3i	29.7d	27.7c	40.3g	32.4d	38.7b	30.5c
Cayman	35.8a	27.8f	-	-	41.4d	31.0j	28.3e	30.3ab	42.6e	31.3e	36.7d	29.1e
Cobra	38.1a	28.1ef	-	-	45.7b	33.0h	30.8c	28.9b	44.4c	31.7de	39.1b	30.8c
Marandu	38.7a	31.9b	-	-	43.5c	36.5c	31.2bc	26.1d	43.8c	35.3b	39.1b	32.1b
Toledo	38.9a	31.1c	-	-	48.8a	37.2ab	31.6b	30.5a	45.8b	38.8a	39.8a	29.8d
BRS Piatã	38.3a	31.5bc	-	-	45.9b	37.0b	31.6b	29.1b	45.4b	36.0b	39.0b	32.9a
BRS Paiaguás	40.7a	31.0c	-	-	49.8a	35.0d	38.8a	29.1b	50.6a	35.5b	40.0a	32.9a
Ruzi	38.8a	28.0ef	-	-	44.9b	33.0h	29.6d	26.3d	45.2b	30.8e	36.1d	27.8f
Humidicola	38.9a	33.1a	-	-	44.8bc	37.3a	31.6b	31.4a	41.6f	35.4b	37.0cd	32.9a
BRO4/3025	39.8a	31.1c	-	-	45.0b	34.0e	29.3d	28.9b	43.4d	34.1c	36.9d	30.2cd
BRO4/3207	40.8a	30.6c	-	-	45.4b	33.7f	29.7d	28.3bc	44.5c	34.2c	37.0cd	30.5c
BRO4/2515	40.4a	29.8d	-	-	45.6b	33.4g	31.0bc	27.4cd	45.7b	34.5fc	37.5c	29.8d
LSD (P<0.05)	7.1	0.7	-	-	1.3	0.2	0.6	1.2	0.7	0.7	0.5	0.6

[1]Not measured; [2]Means within columns followed by the same letter are not significantly different (P>0.05).

Table 9. Neutral detergent fiber concentrations (%) in stems and leaves of *Urochloa* cultivars and lines in wet (May–Oct) and dry (Nov–Apr) seasons from 2015 to 2018 in Ubon Ratchathani, Thailand.

Cultivar/line	First year 2015–2016				Second year 2016–2017				Third year 2017–2018			
	Wet		Dry[1]		Wet		Dry		Wet		Dry	
	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf
Mulato II	62.0d[2]	44.8b	-	-	72.8e	66.2c	59.4g	58.1e	68.7f	61.5f	71.3b	62.7def
Cayman	62.3d	53.6ab	-	-	70.0f	62.1d	54.5i	63.3b	70.7d	58.9h	67.5d	63.6d
Cobra	64.4c	41.3b	-	-	75.6c	63.4cd	58.4h	59.7d	72.4cd	60.3g	69.9c	61.2e
Marandu	67.4b	60.4a	-	-	77.0bc	69.0bc	63.2c	56.5f	72.6cd	65.1e	70.5bc	66.9bc
Toledo	67.4b	62.7a	-	-	78.0b	70.8a	62.3d	62.1b	75.3bc	67.7d	71.9ab	66.9bc
BRS Piatã	66.5b	60.2a	-	-	78.6bc	73.1a	65.2b	60.6c	75.1bc	67.7d	71.8ab	68.2b
BRS Paiaguás	69.2a	59.8a	-	-	81.7a	69.8bc	71.6a	59.6d	77.7a	67.3d	72.0ab	68.2b
Ruzi	66.0b	53.9ab	-	-	75.8c	65.3c	59.6g	53.7g	72.2d	58.9h	64.9e	57.6f
Humidicola	67.0b	63.1a	-	-	77.9b	72.6ab	65.8b	63.6b	73.0c	68.4c	72.6a	71.1a
BRO4/3025	69.8a	66.3a	-	-	79.1b	70.1ab	60.2fg	64.9a	73.9c	70.0a	71.3b	66.8bc
BRO4/3207	68.1ab	61.5a	-	-	78.7b	69.8b	60.0fg	64.1ab	73.3cd	68.0c	71.3b	65.8c
BRO4/2515	69.6a	61.2a	-	-	79.0b	70.3ab	61.5e	60.0cd	76.1b	69.3b	71.8ab	66.2c
LSD (P<0.05)	1.8	14.7	-	-	2.5	3.0	0.6	0.8	1.5	0.6	1.1	1.6

[1]Not measured; [2]Means within columns followed by the same letter are not significantly different (P>0.05).

Discussion

This study has shown that *Urochloa* cultivars not currently used in Thailand (Toledo, BRS Piatã, BRS Paiaguás) may have advantages over the 2 cultivars in general use (Ruzi and Mulato II).

Toledo consistently produced high dry matter yields in both wet and dry seasons, supporting results of a previous study in Thailand, where Toledo produced significantly higher DM yields in both wet and dry seasons than Ruzi and Mulato II (Hare et al. 2009). In Kenya, Toledo (Xaraés) produced significantly more total DM than Mulato II in several trials, but forage quality (CP and NDF concentrations) of Mulato II was superior to that of Toledo (Njarui et al. 2016; Ondiko et al. 2016; Kifuko-Koech et al. 2021). This was in agreement with studies in Ecuador, where Toledo (Xaraés) produced significantly greater total and leaf DM yields than Mulato II, but with lower CP concentrations (Garay et al. 2017). In the current Thailand study, Toledo also produced significantly more leaf DM than Ruzi in all seasons and Mulato II in the second and third wet seasons, but with lower CP concentrations and higher NDF and ADF concentrations than both Ruzi and Mulato II.

Despite the outstanding DM performance of Toledo in this trial and in previous trials (Hare et al. 2009), there is no commercial seed production of Toledo in Thailand, which could limit wide adoption. It is late maturing and flowers later in the dry season than Ruzi and Mulato II, producing few inflorescences, resulting in low or no seed yields (Hare et al. 2015b). Another possible factor that may limit adoption is that most farmers in Thailand use cut-and-carry forage production and Toledo has sharp leaf edges, which can cause discomfort to the handler, whereas Ruzi and Mulato II have softer leaves. We consider Toledo to be better suited to grazing than to cut-and-carry feeding.

In Kenya, BRS Piatã produced higher DM yields than Mulato II in both dry and wet seasons in several trials, but with lower CP concentrations and higher NDF concentrations (Kifuko-Koech et al. 2021). Similarly, a study from Ecuador found that BRS Piatã cut at 4- and 6-week intervals, produced significantly more total DM than Mulato II, but with lower CP concentrations (Garay et al. 2017). In contrast, a study in Rwanda found that BRS Piatã was superior in nutritional characteristics to those of Mulato II (Mutimura et al. 2017). BRS Piatã would be a valuable cultivar to be promoted more in Thailand if seed could be produced locally.

BRS Paiaguás grown in Brazil has proven to be more productive than BRS Piatã in the dry season, producing more dry matter and carrying more stock (Valle et al. 2013; Euclides et al. 2016). In the current study, BRS Paiaguás produced similar accumulated total DM yields to BRS Piatã over the 3 dry seasons. However, the quality of BRS Paiaguás was lower than that of Mulato II and Ruzi, with lower crude protein levels and higher ADF and NDF levels.

The hybrid *Urochloa* cultivars (Mulato II, Cayman and Cobra) and lines (BRO4/3025, BRO4/3207 and BRO4/2515) all accumulated similar total DM yields throughout the study, which were significantly higher than those of Ruzi. Mulato II was slower to establish in the first wet season than the other hybrid cultivars and lines. However, Mulato II had a significantly higher proportion of leaf than the other hybrid cultivars and lines in all seasons. Previous studies have shown that Cayman and Cobra did not show any production and nutritive advantages over Mulato II (Hare et al. 2013, 2015a; Vendramini et al. 2014). Cayman was released for its waterlogging tolerance and Cobra for its strong upright nature for cut-and-carry forage (Hare et al. 2015a). Owing to lack of production advantages over Mulato II and their lower seed yields in village seed production programs, these cultivars are not currently promoted in Thailand. BRO4/3025 has now been released by Grupo Papalotla as cultivar 'Camello' (bit.ly/3Bq5wnF) for its good drought tolerance and decumbent nature making it suitable for grazing. Camello displayed no production advantages over Mulato II and in Mexico, DM production of Camello was lower than that from Toledo, Cobra and Cayman in the dry season (Robles-Vega et al. 2020). Camello has an extended flowering period in the middle of the wet season, July to September, and in trials in Thailand seed yields were negligible (Hare unpublished data).

Marandu established very quickly and, over 3 years, accumulated DM yields that were similar to those of the other cultivars and lines in the dry season, except for Ruzi. Other studies in Thailand have shown that DM yields of Marandu were consistently intermediate between those of Mulato II and Ruzi (Hare et al. 2009). Humidicola grew poorly in the wet season when over 80 % of the herbage is produced. A previous study in Thailand showed that Humidicola compared with several other grass species had intermediate wet season DM production and above average dry season DM production (Hare et al. 1999). Humidicola has a reputation for being invasive, which is not desirable for many pasture species. In the current study after 3 years, Humidicola was spreading out and invading surrounding plots from stolons. Seed production in Thailand is difficult, due to its extended flowering period in the wet season (Hare unpublished data), so it was not evaluated further.

This trial has shown that BRS Piatã and BRS Paiaguás would be ideal replacements for Mulato II and Ruzi in Northeast Thailand for their superior dry season production and they would appeal to smallholder farmers for either cut-and-carry forage or grazing. If seeds of Toledo could be produced in Thailand, this cultivar should be considered for grazing because of its superior DM production over Mulato II and Ruzi.

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