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Evaluation of new hybrid brachiaria lines in Thailand. 1. Forage production and quality

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Abstract

Forty-three new hybrid bracharia lines were evaluated for forage accumulation and nutritive value in Northeast Thailand from 2006 to 2011 in experiments at 2 sites, using Mulato II hybrid brachiaria as a standard for comparison. The parameters evaluated were wet and dry season dry matter (DM) accumulation, leaf:stem ratio, crude protein (CP) concentration and fiber level [acid detergent fiber (ADF) and neutral detergent fiber (NDF)]. No lines consistently displayed superior dry season forage accumulation and leaf:stem ratio over Mulato II. In the wet seasons, 14 lines produced more DM than Mulato II but in only one wet season each. Mulato II produced forage with high leaf:stem ratio in all seasons. Many lines did have significantly higher CP concentrations and lower levels of ADF and NDF than Mulato II, but their forage accumulation and leaf:stem ratio were inferior. Four lines (BR02/1718, BR02/1752, BR02/1794 and BR02/0465) were granted Plant Variety Rights in 2011.

Resumen

En el período 2006–2011 en 2 sitios del noreste de Tailandia (Ubon Ratchathani y Amnart Charoen) fueron evaluadas por su producción de forraje y calidad nutritiva 43 líneas nuevas de híbridos de *Brachiaria*, incluyendo el cultivar (cv.) Mulato II como testigo, procedentes del CIAT. Los parámetros evaluados fueron producción de materia seca (MS) en épocas lluviosa y seca, relación hoja:tallo, concentración de proteína cruda (PC) y niveles de fibra detergente ácido (FDA) y fibra detergente neutro (FDN)]. En la época seca, ninguna de las líneas mostró en forma consistente una producción de MS y relación hoja:tallo superiores que cv. Mulato II. En las épocas lluviosas, 14 líneas produjeron más MS que Mulato II, pero sólo en una época lluviosa cada una. El cultivar Mulato II produjo forraje con alta relación hoja:tallo en todas las épocas. Varias de las líneas presentaron concentraciones de PC significativamente mayores y menores niveles de FDA y FDN que cv. Mulato II, pero su producción de forraje y la relación hoja:tallo fueron inferiores. Las líneas BR02/1718, BR02/1752, BR02/1794 y BR02/0465 alcanzaron la protección de obtención vegetal (*Plant Variety Rights*) en 2011.

Introduction

In 1988 CIAT (Centro Internacional de Agricultura Tropical) in Colombia and EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária) in Brazil began breeding programs on hybridization of brachiaria grasses (Miles et al. 2004). Mulato hybrid brachiaria [*Brachiaria ruziziensis* (now *Urochloa ruziziensis*) x *B. brizantha* (now *U. brizantha*)] was the first hybrid brachiaria cultivar released from the breeding program. Mulato was granted Plant Variety Rights in 2002 (Loch and Miles 2002) and released by the Mexican seed company Grupo Papalotla in 2004 (Miles et al. 2004). Mulato had high forage yields and forage nutritive value but produced very low seed yields (Hare et al. 2007a). Mulato II (*B. ruziziensis* x *B. decumbens* (now *U. decumbens*) x *B. brizantha*), the second hybrid brachiaria cultivar released, was granted Plant Variety Rights in 2004 (Loch and Miles 2004) and released by Grupo Papalotla

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in 2005 (Argel et al. 2007). Mulato II was similar to Mulato but demonstrated excellent drought tolerance and superior seed yields (Hare et al. 2007b; 2007c) and in 2005, Grupo Papalotla replaced Mulato with Mulato II.

From 2006 to 2011, further studies were conducted by Grupo Papalotla in Thailand on selected lines from the BR02 and BR06 hybrid brachiaria collections from CIAT, and 2 lines from the MX02 collection from Mexico, with the aim of identifying lines with overall superior forage attributes. BR02 and BR06 are the names of new hybrid progeny from the CIAT breeding program in spaced plant trials in Colombia between 2002 and 2006. MX02 is the name given to new hybrid progeny, from original BR0 progeny that were further evaluated by Grupo Papalotla in Mexico during 2002–2005. New cultivar selection in the Thailand experiments focused on dry matter yield, forage nutritive value, seed production, drought tolerance and persistence.

This paper describes these studies on forage accumulation and nutritive value of hybrid brachiaria lines. A second paper (Hare et al. 2015) describes research on the seed production of these same lines.

Materials and Methods

Experiment 1 – BR02 and MX02 collections

A field experiment was conducted at Ubon Ratchathani University, Thailand, (15° N, 104° E; 130 masl) from 2006 to 2008. The site was on an upland sandy low humic gley (Paleaquult) soil (Roi-et series) (Mitsuchi et al. 1986). Soil samples, taken at planting in May 2006, showed that the soil was acid (pH 4.6; water method), and low in organic matter (1.1%), N (0.04%), P (3.5 ppm; Bray II extraction method) and K (27.4 ppm). Prior to planting the experiment, the site had grown a mixture of native grasses and legumes for many years. Thirteen hybrid brachiaria lines from the BR02 collection, 2 from the MX02 collection and cv. Mulato II (Table 3) were planted in June 2006 in a randomized complete block design with 4 replications; details of field crop management are presented in Table 1. Seedlings were grown in a nursery and transplanted into the field plots with 50 x 50 cm spacings (60 plants per plot). At each sampling cut, the forage in six 0.25 m^2 quadrats per plot was cut 5 cm from ground level and weighed fresh. A 300 g subsample was sorted into leaves and stems and dried at 70 °C for 48 h to determine dry weight. The dried subsamples were analyzed for total N (Kjeldahl method) in order to calculate crude protein (CP, %N x 6.25), acid detergent fiber (ADF, Van Soest method) and neutral detergent fiber (NDF, Van Soest method) concentrations. After each sampling cut, the remaining herbage in the plots was cut to 5 cm from ground level and removed.

Experiment 2 – BR06 collection

This study was conducted at a site, 90 km north of Ubon Ratchathani University, at the Amnart Charoen Livestock Development Centre, Amnart Charoen province, Northeast Thailand (15.5° N, 104.4° E; elevation 168 masl) from 2008 to 2011. The site was on an upland sandy reddish brown earth (Haplustalf) soil (Chatturat series) (Mitsuchi et al. 1986). Soil samples taken at planting in July 2008 showed that the soil was acid (pH 4.6; water method), very sandy (75% sand), and low in organic matter (0.4%), N (0.04%) and K (31 ppm), and adequate for P (25.2 ppm; Bray II extraction method). Prior to cultivation, the site had been growing Tanzania guinea grass (*Panicum maximum*, now *Megathyrsus maximus*) for 5 years.

Twenty-eight hybrid brachiaria lines from the BR06 collection, 4 from the BR02 collection (Table 7), and

Table 1. Field crop management during evaluation of hybrid brachiaria lines (Experiment 1).

Field cultivation	Plowing x 2, disking x 1, harrowing x 1
Plot size	3 m x 5 m with 50 cm walkway around plots and 1 m between replications
Planting date	1–5 Jun 2006
Cleaning cut	3 Aug 2006; all plots cut to 5 cm above ground level
Sampling harvests	
First wet season	2006: 13 Sep & 2 Nov
First dry season	2007: 10 Jan, 21 Mar & 30 Apr
Second wet season	2007: 11 Jun, 26 Jul, 10 Sep & 29 Oct
Second dry season	2008: 2 Jan & 25 Apr
Harvest quadrats/plot	Six 0.25 m^2 random quadrats
Fertilizer	Nil at planting; 200 kg/ha NPK (15:15:15) after every harvest

cvv. Mulato II, Toledo (*B. brizantha*) and Marandu (*B. brizantha*) were planted in a randomized complete block design with 4 replications in July 2008. Seedlings were grown in a nursery and transplanted into the field plots in 50 x 50 cm spacings (48 plants per plot). Details of crop management are presented in Table 2. Sampling and laboratory analyses were the same as for Trial 1.

Data from the experiments were subjected to analysis of variance, using the IRRISTAT program from the International Rice Research Institute (IRRI). Entry means were compared by Fisher's protected LSD ($P \leq 0.05$).

Results

Rainfall

Experiment 1 – BR02 and MX02 collections. Rainfall at Ubon Ratchathani in 2006 and 2007 was 9 and 11%, respectively, below the 13-yr mean (Figure 1). Rainfall in the dry seasons (Nov–Apr) was above average in 2006/2007 (33%) but nearly 90% below average in 2007/2008, with only 26 mm falling from November to April.

Table 2. Field crop management during evaluation of hybrid brachiaria lines (Experiment 2).

Field cultivation	Plowing x 2, disking x 1, harrowing x 1
Plot size	3 m x 4 m with 50 cm walkway around plots and 1 m between replications
Planting date	26–28 Jul 2008
Cleaning cut	8 Sep 2008; all plots cut to 5 cm above ground level
Sampling harvests	
First wet season	2008: 20 Oct
First dry season	2008: 18 Dec
	2009: 28 Apr
Second wet season	2009: 16 Jun, 3 Aug, 15 Sep & 29 Oct
Second dry season	2010: 19 Jan & 27 Apr
Third wet season	2010: 9 Jun, 4 Aug, 14 Sept & 26 Oct
Third dry season	2011: 26 Apr
Harvest quadrats/plot	Six 0.25 m^2 random quadrats
Fertilizer	Nil at planting; 200 kg/ha NPK (15:15:15) after every harvest

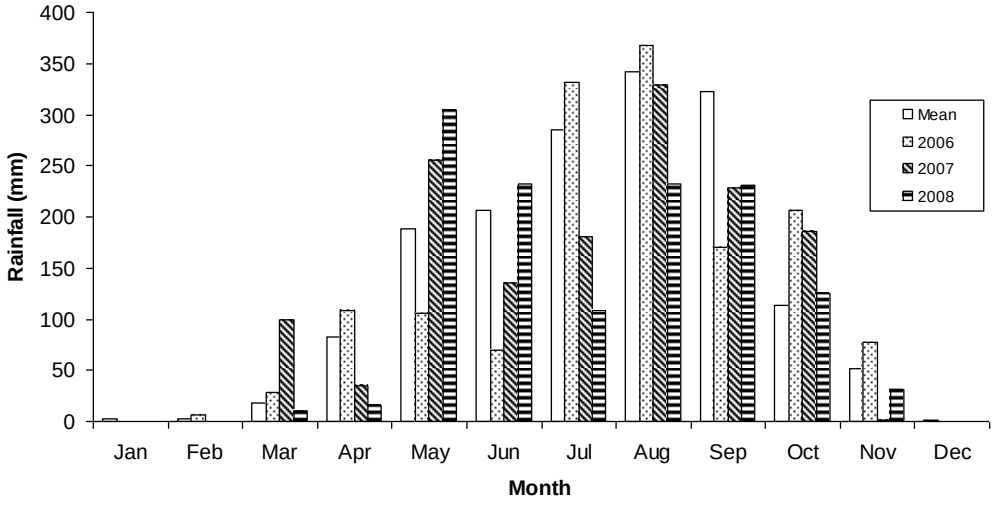

Figure 1. Rainfall at the Ubon Ratchathani University meteorological station, 1 km from the research site, during the experiment and the 13-yr mean (2000–2012).

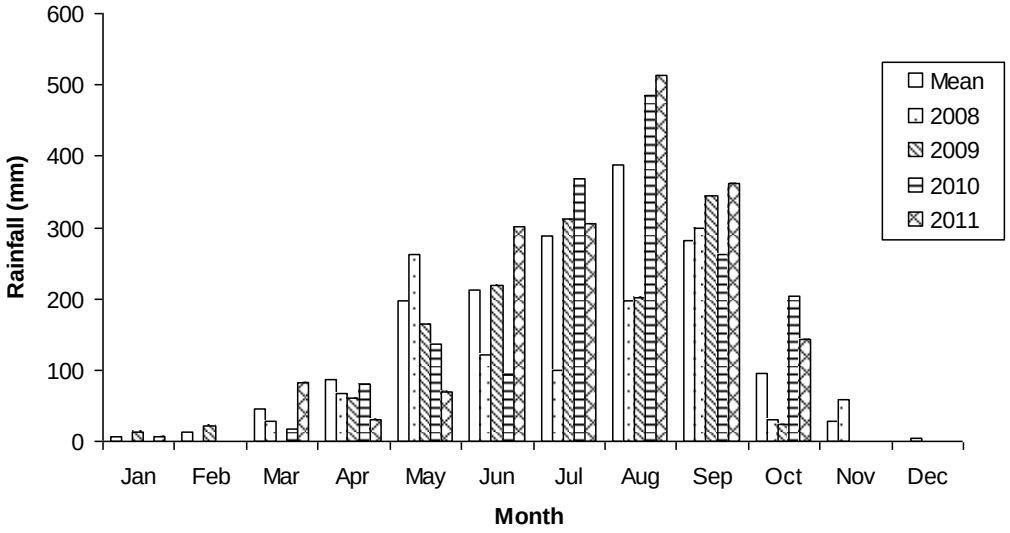

Figure 2. Rainfall at the Amnart Charoen meteorological station, 9 km from the research site, during the experiment and the 13-yr mean (2000–2012).

Experiment 2 – BR06 collection. Rainfall at Amnart Charoen in 2008 and 2009 was, respectively, 30 and 20% below the 13-yr mean, but 2010 rainfall was slightly above the mean (Figure 2). Rainfall in the dry seasons (Nov–Apr) during the experiment was 30% (2008/2009), 47% (2009/2010) and 74% (2010/2011) below the mean.

Forage accumulation and nutritive value

Experiment 1 – BR02 and MX02 collections. Only 2 lines accumulated more DM than Mulato II: BR02/1752 in the first dry season and second wet season and BR02/1718 in the second dry season (Table 3). BR02/0768 was the only line that produced a higher leaf proportion than Mulato II, which was in the second dry season.

Crude protein concentrations were higher in the dry season than in the wet season and higher in leaves than in stems (Table 4). BR02/1452 had higher CP concentrations than Mulato II in both seasons and plant parts.

ADF concentrations were lower in the dry season than in the wet season and in leaves than in stems (Table 4). BR02/1752, 1794 and 1452 had overall lower ADF concentrations than Mulato II, while BR02/0465 and MX02/1263 had higher ADF concentrations.

Lower NDF concentrations were found in the dry season than in the wet season and in leaves than in stems (Table 4). BR02/1752 had lower overall NDF concentrations, while BR02/0465 and MX02/1263 had higher NDF concentrations.

Experiment 2 – BR06 collection. Several BR06 lines accumulated significantly more DM than Mulato II: BR06/0206, 0387, 0423, 0850, 1348, 1366, 1388, 1454 and 2058 and Marandu in the first wet season; and BR06/0206, 1175, 1278, 1415 and 1454 in the third wet season (Table 5). In the second wet season, only Toledo accumulated more DM than Mulato II, while all BR06 lines, except for BR06/1000, 1278 and 1696, accumulated significantly less DM than Mulato II.

No lines or cultivars accumulated significantly more DM than Mulato II in the dry seasons (Table 5). In the first dry season, Mulato II accumulated significantly more DM than more than half the BR06 lines, BR02/1718 and BR02/1372. In the second dry season, DM accumulation was similar for all lines and cultivars, as it was in the third dry season, except for BR06/1433, 1567 and 1922, which produced significantly less DM than Mulato II.

No hybrid line or cultivar produced a higher leaf proportion than Mulato II throughout the trial at Amnart Charoen (Table 6). Mulato II produced a higher leaf proportion than all hybrids and other cultivars in all seasons, except: Marandu, BR06/1000, 1567, 1932 and 2020 in the first wet season; Toledo, BR02/1372, BR06/0012, 0387, 0531, 0584, 1000, 1175 and 1922 in the first dry season; BR06/0204 and 0423 and Toledo in the second wet season; and BR06/1922 in the second and third dry seasons.

Table 3. Dry matter accumulation and leaf percentages in forage DM of hybrid brachiaria lines in wet (May–October) and dry (November–April) seasons from 2006 to 2008 in Ubon Ratchathani, Thailand.

Hybrid line/ cultivar	Dry matter accumulation (kg/ha)				Leaf percentage (%)			
	First year		Second year		First year		Second year	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mulato II	4,460	3,280	10,570	2,320	69	85	72	81
BR02/0465	3,720	3,240	11,590	2,480	66	77	66	78
BR02/0768	3,680	3,910	10,650	2,240	68	87	74	88
BR02/0771	3,770	3,580	10,870	2,330	70	80	71	83
BR02/0799	3,650	2,460	10,730	2,520	64	85	63	80
BR02/1245	3,900	3,370	10,400	2,170	62	78	64	80
BR02/1372	3,910	3,960	8,720	2,460	60	76	66	78
BR02/1452	2,680	2,320	7,670	1,930	70	80	67	80
BR02/1485	4,920	3,410	11,790	2,560	60	81	65	79
BR02/1718	4,790	3,710	10,390	2,930	51	77	67	76
BR02/1728	3,810	3,510	10,560	2,160	63	79	56	81
BR02/1747	4,230	3,220	10,540	2,280	51	77	56	76
BR02/1752	4,200	3,990	12,600	2,160	60	78	55	79
BR02/1794	3,700	3,300	11,150	2,500	61	78	55	77
MX02/1263	5,010	3,230	10,860	2,110	63	81	66	80
MX02/1423	4,150	3,190	10,570	2,050	56	77	56	73
Mean	4,040	3,360	10,640	2,230	62	80	64	79
LSD (P<0.05)	990	700	1,350	430	5.2	4.2	3.7	4.7
F ratio	2.78	3.48	5.73	2.62	10.06	5.39	22.56	4.11
Probability	0.004	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001

Table 4. Average crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations in stem (S) and leaf (L) of hybrid brachiaria lines in wet (May–October) and dry (November–April) seasons from 2006 to 2008 in Ubon Ratchathani, Thailand.

Hybrid line/ cultivar	CP (%)				ADF (%)				NDF (%)			
	Wet		Dry		Wet		Dry		Wet		Dry	
	S	L	S	L	S	L	S	L	S	L	S	L
Mulato II	4.7	8.6	5.9	9.7	37.4	30.9	33.1	28.6	66.0	58.4	62.1	53.5
BR02/0465	4.5	9.1	6.2	10.1	39.5	33.7	34.3	30.5	67.0	61.3	63.2	57.4
BR02/0768	4.5	8.9	6.4	9.6	37.8	29.6	32.7	27.1	65.7	58.0	60.5	53.2
BR02/0771	5.5	9.9	7.2	9.8	38.3	29.7	33.9	27.0	65.3	56.8	61.7	52.6
BR02/0799	5.4	8.2	7.7	10.1	36.4	29.5	30.8	26.2	64.8	59.3	61.1	54.9
BR02/1245	4.3	8.1	6.0	9.3	40.1	30.4	34.2	27.1	68.7	58.3	63.6	54.8
BR02/1372	4.9	8.9	6.0	9.4	38.5	30.9	35.3	27.0	65.5	56.9	62.7	53.4
BR02/1452	5.4	9.6	7.3	10.2	37.3	29.4	33.4	26.0	66.3	56.6	61.7	51.9
BR02/1485	4.4	9.2	6.3	9.7	39.5	30.0	34.7	28.0	67.6	59.0	64.6	53.8
BR02/1718	5.2	9.4	7.0	9.4	37.5	32.3	31.6	27.6	63.2	56.6	59.4	53.0
BR02/1728	4.8	9.6	6.1	9.8	39.8	31.1	35.6	29.0	66.6	59.2	64.3	54.8
BR02/1747	4.4	8.7	5.7	8.9	38.2	32.3	32.5	29.5	66.9	57.3	62.3	54.4
BR02/1752	4.1	9.1	5.8	8.7	36.6	30.0	32.4	27.8	65.8	57.0	60.5	52.5
BR02/1794	4.4	8.6	6.3	8.8	38.2	30.8	32.8	27.2	66.3	58.6	61.9	52.6
MX02/1263	4.1	8.1	6.6	9.7	40.0	29.7	34.5	29.9	69.9	60.6	63.9	54.1
MX02/1423	4.4	8.8	6.4	9.9	39.8	29.1	34.1	27.0	66.9	57.2	61.9	52.6
Mean	4.7	8.9	6.4	9.6	38.4	30.6	33.5	27.8	66.4	58.2	62.2	53.7
LSD (P<0.05)	0.59	0.90	0.90	0.81	0.93	0.82	0.79	0.76	1.00	0.91	0.85	0.73
F ratio	7.17	15.47	21.7	5.1	23.1	58.9	24.6	22.7	61.5	31.0	48.3	51.5
Probability	<0.001	0.001	0.014	0.007	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 5. Dry matter accumulation (kg/ha) of hybrid brachiaria lines and cultivars in wet (May–October) and dry (November–April) seasons from 2008 to 2011 in Amnart Charoen, Thailand.

Hybrid line/	First year 2008/2009		Second year 2009/2010		Third year 2010/2011	
cultivar	Wet	Dry	Wet	Dry	Wet	Dry
Mulato II	1,990	4,390	9,770	1,280	5,940	1,070
BR02/1794	2,670	3,680	8,790	1,150	5,300	930
BR02/0465	1,490	4,030	10,730	1,540	5,870	1,180
BR02/1718	2,390	3,490	9,340	1,300	5,430	1,210
BR02/1372	2,370	3,140	7,390	1,410	5,330	1,170
Marandu	3,110	4,240	9,360	1,270	6,620	1,300
Toledo	2,800	4,340	11,690	940	5,970	1,140
BR06/0012	2,260	3,270	7,040	1,200	6,120	890
BR06/0204	2,290	3,110	6,930	1,160	6,000	650
BR06/0206	2,990	3,870	8,330	1,240	7,510	810
BR06/0387	2,870	3,070	6,560	1,300	6,260	850
BR06/0405	2,680	3,390	7,480	1,200	6,280	890
BR06/0423	3,290	3,740	7,710	1,450	6,580	1,280
BR06/0531	2,630	4,050	8,520	1,510	6,860	1,130
BR06/0584	2,610	3,660	7,640	1,160	6,190	790
BR06/0850	2,890	3,940	8,590	1,020	6,530	690
BR06/1000	2,330	3,210	8,730	1,630	7,690	780
BR06/1132	2,460	3,430	7,190	970	6,360	760
BR06/1175	2,480	3,330	7,680	1,270	7,180	860
BR06/1254	2,820	3,200	7,980	1,240	6,770	1,010
BR06/1278	2,860	3,910	8,820	1,880	7,650	1,440
BR06/1348	3,090	4,390	8,460	1,200	6,860	740
BR06/1366	3,030	3,410	8,040	1,180	6,700	990
BR06/1388	2,890	3,910	7,250	1,140	5,960	790
BR06/1415	2,760	3,430	7,460	1,050	7,790	810
BR06/1433	2,800	3,410	6,930	790	6,270	580
BR06/1454	2,960	3,480	8,150	1,230	7,870	900
BR06/1567	1,940	3,660	7,110	860	4,430	610
BR06/1696	2,750	3,660	8,820	1,740	6,320	1,090
BR06/1832	2,820	3,750	6,810	1,340	5,160	1,170
BR06/1922	2,740	2,970	6,710	880	4,090	540
BR06/1932	2,470	3,450	8,410	1,420	6,060	1,010
BR06/2020	2,380	3,740	8,190	1,260	6,100	810
BR06/2058	2,970	3,300	8,210	1,150	4,820	900
BR06/2204	2,420	3,240	7,280	1,280	4,910	1,040
Mean	2,640	3,610	8,120	1,250	6,220	940
LSD (P<0.05)	870	780	1,160	ns	1,190	420
F ratio	2.70	2.83	5.20	1.24	4.83	1.77
Probability	<0.001	<0.001	<0.001	0.202	<0.001	0.002

Crude protein concentrations in forage were higher in the dry season than the wet season and in leaves than in stems (Table 7). All BR06 lines had CP concentrations either significantly higher than or similar to those of Mulato II in both stems and leaves in the wet season and in stems in the dry season, while only BR06/1922 and 2058 had significantly higher dry season leaf CP levels than Mulato II.

ADF and NDF concentrations varied between seasons, plant parts and hybrid lines (Table 7). Dry season concentrations were lower than in the wet and leaf concentrations were lower than in stems. Most BR06 hybrid lines had significantly lower dry season leaf ADF and leaf and stem NDF concentrations than Mulato II, while some had lower leaf and stem ADF concentrations in the wet season. While leaf NDF concentrations in the wet season in the BR06 hybrid lines were generally lower than in Mulato II, stem NDF concentrations were generally higher in the hybrids.

Table 6. Leaf proportion (%) of forage DM of hybrid brachiaria lines and cultivars in wet (May–October) and dry (November–April) seasons from 2008 to 2011 in Amnart Charoen, Thailand.

Hybrid line/	First year 2008/2009		Second year 2009/2010		Third year 2010/2011	
cultivar	Wet	Dry	Wet	Dry	Wet	Dry
Mulato II	66	74	70	83	72	88
BR02/1794	52	70	54	75	56	81
BR02/0465	56	67	65	73	65	78
BR02/1718	38	69	64	73	67	76
BR02/1372	43	72	67	76	68	81
Marandu	60	74	63	77	64	80
Toledo	64	73	68	76	69	78
BR06/0012	58	75	64	76	65	77
BR06/0204	61	60	69	69	64	77
BR06/0206	49	67	63	71	64	75
BR06/0387	52	72	66	75	63	79
BR06/0405	33	69	55	73	61	78
BR06/0423	58	70	68	72	66	73
BR06/0531	58	72	66	76	67	76
BR06/0584	54	72	65	72	64	73
BR06/0850	52	62	51	65	54	68
BR06/1000	64	75	62	77	64	79
BR06/1132	40	61	61	68	63	76
BR06/1175	53	75	57	77	62	80
BR06/1254	57	68	65	74	65	80
BR06/1278	58	70	61	72	66	73
BR06/1348	50	65	64	68	62	71
BR06/1366	28	62	55	67	61	71
BR06/1388	40	66	54	66	57	67
BR06/1415	57	68	61	70	61	72
BR06/1433	45	69	59	72	64	74
BR06/1454	51	69	56	70	62	72
BR06/1567	62	69	65	72	63	76
BR06/1696	55	69	62	72	59	75
BR06/1832	52	65	60	67	58	68
BR06/1922	54	76	62	81	65	86
BR06/1932	60	72	65	74	63	75
BR06/2020	60	66	58	71	60	75
BR06/2058	41	70	66	74	64	78
BR06/2204	58	70	66	72	67	76
Mean	53	69	62	74	63	76
LSD (P<0.05)	7.2	3.8	2.9	4.3	2.6	4.8
F ratio	12.15	8.95	20.18	7.89	15.77	6.91
Probability	<0.001	<0.001	<0.001	<0.001	0.110	<0.001

Table 7. Average wet season (May–October) and dry season (November–April) crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentrations in stem (S) and leaf (L) of hybrid brachiaria lines and cultivars from 2008 to 2011 in Amnart Charoen, Thailand.

Hybrid line/ cultivar	CP (%)				ADF (%)				NDF (%)			
	Wet		Dry		Wet		Dry		Wet		Dry	
	S	L	S	L	S	L	S	L	S	L	S	L
Mulato II	6.2	8.3	7.0	11.8	36.9	31.2	33.7	28.0	64.6	59.8	60.4	52.1
BR02/1794	6.0	7.8	7.0	9.4	38.2	31.0	32.4	28.2	65.7	59.6	56.9	51.6
BR02/0465	5.5	8.5	7.7	11.9	39.9	34.3	36.3	30.9	66.8	64.7	63.3	56.5
BR02/1718	6.3	8.5	7.4	10.6	37.7	31.6	33.3	28.6	63.0	58.7	58.0	51.5
BR02/1372	7.1	8.8	7.1	9.8	38.5	30.9	35.5	28.2	64.3	58.7	61.9	50.2
Marandu	5.5	8.5	6.4	9.8	38.3	32.9	33.8	30.4	66.5	63.6	61.4	57.5
Toledo	4.4	6.8	5.5	8.4	39.3	34.5	35.0	32.	68.0	64.8	61.6	58.7
BR06/0012	7.4	9.0	8.9	9.7	39.6	33.1	34.0	31.0	65.7	60.2	59.6	53.1
BR06/0204	7.9	9.1	7.7	10.7	36.3	31.1	32.7	27.5	62.5	58.5	60.0	49.9
BR06/0206	7.0	9.1	8.2	11.3	39.0	31.5	33.7	27.2	65.9	60.2	59.6	50.9
BR06/0387	7.7	9.3	10.9	11.4	39.5	31.0	30.7	27.9	65.8	58.6	52.2	48.5
BR06/0405	7.2	8.8	8.2	11.1	39.5	31.7	33.7	27.8	66.3	58.5	56.5	49.1
BR06/0423	7.0	8.3	8.0	9.8	37.0	31.1	32.5	28.0	66.3	58.5	56.9	50.1
BR06/0531	6.3	8.6	7.0	10.7	38.0	30.4	33.9	27.6	65.5	57.9	56.6	47.9
BR06/0584	7.5	8.1	10.1	10.7	37.7	31.3	30.9	27.9	65.4	60.5	57.7	51.1
BR06/0850	6.0	8.3	7.5	10.8	39.6	30.5	34.2	26.7	69.0	60.7	62.9	51.2
BR06/1000	6.6	9.2	7.9	10.6	38.0	30.8	33.0	27.6	65.4	57.0	58.7	48.3
BR06/1132	6.5	8.6	6.8	10.5	37.7	31.3	33.2	28.1	65.4	59.8	61.1	51.0
BR06/1175	6.0	9.2	8.5	10.9	37.7	31.3	31.3	27.2	65.0	58.3	57.8	49.8
BR06/1254	7.2	8.1	10.9	12.0	37.8	30.6	31.8	26.1	64.4	59.1	57.4	49.1
BR06/1278	6.6	8.9	8.6	11.7	39.3	31.3	33.3	27.6	64.8	58.0	58.2	48.8
BR06/1348	7.3	8.5	7.1	10.8	38.1	30.5	34.2	27.2	64.5	58.4	60.2	49.3
BR06/1366	6.6	8.9	8.8	11.8	39.0	31.5	34.1	27.7	66.9	59.5	58.8	49.9
BR06/1388	6.6	8.8	8.6	10.5	40.1	31.3	34.2	27.5	67.5	58.8	59.5	51.0
BR06/1415	6.7	8.0	7.4	11.0	38.5	30.9	34.3	27.6	67.7	60.5	60.4	51.8
BR06/1433	8.5	9.3	8.3	11.8	38.9	30.7	33.5	26.2	65.3	57.4	55.8	49.0
BR06/1454	7.6	9.2	9.5	11.7	38.0	29.3	34.2	25.6	64.2	56.0	57.4	48.2
BR06/1567	7.2	7.9	8.2	10.6	38.8	32.6	32.5	27.7	65.5	60.1	58.2	51.9
BR06/1696	6.8	7.9	7.5	10.1	39.0	30.6	34.2	28.1	65.5	57.3	59.0	51.0
BR06/1832	7.2	8.1	8.8	11.4	38.1	30.3	34.1	28.0	66.0	59.4	60.3	51.5
BR06/1922	7.4	8.4	9.5	13.2	37.6	29.5	31.7	25.6	65.1	57.3	59.1	48.2
BR06/1932	7.0	8.4	7.5	10.8	38.0	30.1	32.4	26.3	65.3	58.8	58.8	50.7
BR06/2020	7.6	8.9	9.0	10.9	37.2	29.4	33.3	27.0	63.9	56.0	59.6	49.8
BR06/2058	7.1	8.8	7.6	13.1	37.0	29.3	31.8	24.3	65.0	57.1	58.7	47.6
BR06/2204	7.4	8.6	7.8	11.1	36.5	29.2	32.6	25.9	64.2	59.1	58.4	50.3
Mean	6.8	8.6	8.1	10.9	38.5	31.1	33.3	27.7	65.5	59.2	58.9	50.8
LSD (P<0.05)	0.41	0.42	0.62	0.60	0.31	0.23	0.32	0.27	0.35	0.25	0.66	0.46
F ratio	31.5	16.2	27.8	20.6	127.6	394.5	117.4	271.3	312.4	606.4	84.6	238.5
Probability	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Discussion

This study suggests that some of the hybrid lines tested might have advantages over Mulato II in terms of wet season DM accumulation, but there was little evidence of any superiority in terms of DM accumulation during the dry season, when extra forage might be most needed. While, in some seasons, some BR02 and BR06 hybrid lines produced more forage than Mulato II, particularly in the wet season, only 2 hybrid lines produced significantly more DM than Mulato II in the dry season; BR02/1752 and BR02/1718 in one dry season each at the Ubon Ratchathani site. At the Amnart Charoen site, none of the BR06 lines accumulated more DM than Mulato II in the dry, but several did accumulate significantly more DM than Mulato II in the first and third wet seasons.

Forage accumulation was inconsistent, as nine BR06 lines produced, on average, 50% more DM than Mulato II in the first wet season and 5 lines produced, on average, 28% more DM than Mulato II in the third wet season. By contrast, in the second wet season at the Amnart Charoen site, 25 of the twenty-eight BR06 lines produced significantly less DM (28% less) than Mulato II. The superior DM accumulation of BR02/1752 over Mulato II (12,600 vs. 10,600 kg/ha) in the second wet season at the Ubon Ratchathani site was at variance with other reports (Hare et al. 2013a; Vendramini et al. 2014), where BR02/1752 displayed no forage production advantages over Mulato II.

A distinct advantage of Mulato II in these experiments was the superior leaf proportion in forage compared with the other hybrid lines, averaging 66–72% in the wet season and 74–88% in the dry season. The high production of lush, soft green leaves and low stem DM has always made Mulato II an attractive forage for livestock (Argel et al. 2007; Hare et al. 2009).

Concentrations of CP in both leaves and stems were not high in both experiments, and were particularly low (4.3–5.5%) in stems in the wet season in Experiment 1 (Table 4). Interestingly, many of the BR06 lines had superior stem CP concentrations to Mulato II but similar leaf CP concentrations. Compared with other studies on hybrid brachiaria grasses, CP concentrations in these experiments were generally inferior. In Florida, CP concentrations in whole plants (leaf and stem) of Mulato II averaged 13% in one study, 10% in a second (Vendramini et al. 2012) and 11.4% in a third (Vendramini et al. 2014). In cutting trials in Thailand, Mulato II, BR02/1752 and BR02/1794 produced high CP concentrations (8.8–9.4% in stems and 12.6–13.2% in leaves), only when cut every 30 days (Hare et al. 2013a). However, occasionally, there have been instances of high CP concentrations in hybrid brachiarias. In seed-production trials in Thailand, Mulato and Mulato II forage cut at seed-crop closing produced leaf CP levels up to 17.5% (Hare et al. 2007b). In those trials 200 kg/ha NPK (15:15:15) was applied monthly. In Florida, Mulato pastures, that received 150 kg N/ha in 3 applications (April, June and August), contained CP levels up to 17.2% and averaged 13.8% over 2 years (Inyang et al. 2010). However, such results are not common, and hybrid brachiarias appear to average about 7–11% CP in leaves in Thailand.

Many BR06 lines and BR02/1752 had lower fiber (ADF and NDF) percentages than Mulato II, particularly in the wet season. All hybrid lines and cultivars tested in these trials produced far lower fiber levels than *Panicum maximum* cultivars grown in adjacent trials at the same site (Hare et al. 2013b).

The higher CP concentrations and lower fiber levels than Mulato II in many BR06 lines make them appear attractive, but none produced more dry season forage than Mulato II and they generally had poorer leaf:stem ratios than Mulato II. Several did produce more wet season forage than Mulato II in some seasons but this was not consistent. In addition, their seed yields tended to be erratic and low compared with Mulato II (Hare et al. 2015). More studies need to be conducted on these lines before they could be considered superior to Mulato II and likely to warrant release as a cultivar.

Two BR02 lines have already been released as cultivars. The first was BR02/1752, which was granted Plant Variety Rights in 2011 (Loch et al. 2011b) and released as cv. Cayman by Grupo Papalotla in 2012 (Pizarro et al. 2013). In the current studies Cayman produced more DM than Mulato II in only one wet season and one dry season, and had significantly lower leaf production than Mulato II. The superior leaf production of Mulato II compared with Cayman was also found in another study at Ubon Ratchathani University (Hare et al. 2013a). The nutritive value of Cayman compared with Mulato II was variable, with overall lower CP concentrations but also lower fiber levels. However, Cayman had higher stem CP concentrations and consistently lower fiber levels than Mulato II in a separate study at Ubon Ratchathani University (Hare et al. 2013a). The main factor that justified Cayman's release as a cultivar was its superior waterlogging tolerance compared with Mulato II (Pizarro et al. 2013). It produced a mass of adventitious roots (1,065/plant) following 55 days of waterlogging compared with only 4/plant for Mulato II (Pizarro and Hare 2014). While Cayman's tolerance of waterlogging is lower than that of *B. humidicola* (now *Urochloa*

humidicola), Cayman has superior nutritional value to *B. humidicola*. There is a strong demand for high quality waterlogging-tolerant forage cultivars.

BR02/1794 was granted Plant Variety Rights in 2011 (Loch et al. 2011c) and released by Grupo Papalotla as cv. Cobra in 2014 (E. Stern pers. comm.). In this study, while Cobra had similar DM production to Mulato II, it had significantly lower leaf proportion, particularly in the wet season, where leaf:stem ratio, averaged across both experiments, was 55:45 for Cobra and 70:30 for Mulato II (data not shown). Two main attributes have justified Cobra's release: The first is its strong upright nature, which is ideal for cut-and-carry forage systems. Secondly, its seed production is superior to that of Mulato II, as in 4 of 5 seed harvests, Cobra produced significantly more seed than Mulato II (Hare et al. 2015).

Two other lines, BR02/1718 and BR02/0465, have been granted Plant Variety Rights (Loch et al. 2011a; 2011d) but have not been released as cultivars. BR02/1718 had similar DM production to Mulato II in all seasons but lower leaf production. BR02/0465 produced more DM in the wet season than Mulato II but had lower leaf production. Both lines produced significantly higher seed yields than Mulato II in some seasons (Hare et al. 2015).

While 43 hybrid brachiaria lines were evaluated in this study from 2005 to 2011, only 2 lines, BR02/1752 (cv. Cayman) and BR02/1794 (cv. Cobra), had some attributes superior to those of Mulato II, i.e. upright habit and waterlogging tolerance, that warranted their release as named cultivars. They were not equal to Mulato II in terms of DM yield and nutritive value in this study. While some other lines showed greater DM production in some wet seasons, the superiority displayed in these studies would not justify their being considered for release. Further studies would need to be done before such a decision could be made.

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