Tropical Grasslands (1999) Volume 33, 65–74

Pasture grass and legume evaluation on seasonally waterlogged and seasonally dry soils in north-east Thailand

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Abstract

Tropical pasture grasses and pasture legumes were evaluated for seasonally wet and seasonally dry lowland pastures (1500 mm average annual rainfall) on infertile soils in north-east Thailand. The best grass was *Paspalum atratum* (BRA009610) which produced on average, more than 20 t/ha DM in a 6-month wet season. This grass has been released in Thailand as cv. Ubon. *Setaria sphacelata* var. *sericea* cv. Splenda and *Paspalum plicatulum* grew well but were less productive than *P. atratum*. *Brachiaria decumbens* grew well on drier sites, particularly during the dry season when it produced over 10 t/ha DM in 6 months. *Brachiaria ruziziensis* was very productive in the first season but productivity declined in following years on waterlogged soils which dried out rapidly in the dry season. *Digitaria milanjiana* cv. Jarra was slow to establish but was very productive in the third year on well-drained soils, producing over 27 t/ha DM in the wet season. *Stylosanthes guianensis* cv. Graham and *S. hamata* cv. Verano were the best legumes followed by *Calopogonium mucunoides*, but they failed to grow in the second dry season. *Macroptilium gracile* cv. Maldonado grew well in the wet season following planting, but it did not persist. On seasonally wet waterlogged and seasonally dry soils, *P. atratum* appears the best grass to recommend for smallholder dairy farmers but no legumes performed well enough to be recommended at this stage.

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Introduction

North-east Thailand is an elevated plateau of approximately 17 M ha, 100–300 metres above sea level. The region lies between 14° and 19°N latitude and experiences a tropical savannah climate with pronounced seasonal rainfall (80–90% between May–October). Annual rainfall varies from about 1000 mm in the west to nearly 2000 mm in the east.

It is the major livestock region in Thailand, with stock numbers in 1995 being: beef cattle 2.6 M (6.3 M head for the whole country); buffalo 3.5 M (4.6 M) and dairy cows 60 000 (240 000 head) (Anon. 1997). Beef cattle and buffalo numbers have declined slightly over the past 10 years but dairy cow numbers have increased 4 fold (Chantalakhana 1994). There are now more than 19 000 dairy farms in Thailand. Farmers are attracted to dairying because of the regular income and the opportunity to make good profits if their management is good.

Nearly 80% of milk consumed in Thailand has to be imported. Dairy farm sizes are small (2–4 ha), with about 12 cows per farm, of which only 6 are milking at any one time (Chantalakhana 1994). Cows average 7–8 kg/d raw milk (1800–2000 kg/lactation), have a lactation period of 200 days and a calving interval of 400–450 days. Purchase of animal feed represents nearly 60% of farmers' direct costs and productivity increases are limited by feed supply.

One of the biggest improvements to dairy cow productivity and farm profitability is through the use of properly managed improved pastures. Research in Thailand has shown that cows grazing good leafy common guinea grass (*Panicum maximum*) and caribbean stylo (*Stylosanthes hamata* cv. Verano) pastures, without concentrates, produced more than 10 kg milk/cow/d. Greater economic returns were achieved from pasture-only grazing systems than from pasture-concentrate systems (Lekchom *et al*. 1992; Witayanuparpyeunyong *et al*. 1992). This research was conducted in central Thailand on well drained red-brown laterite soils of moderate fertility, which represent less than 1% of the area in north-east Thailand.

In north-east Thailand detailed pasture research has been carried out on well drained upland red-yellow latosols and red-yellow podzolic soils (Shelton *et al.* 1979) which make up only about 12% of the area. Dairy farming is now expanding on to former rice paddy land comprising grey podzolic soils (Khorat soils) and low humic gley soils (Roi-et soils), covering more than 40% of the region.

These 2 soils are largely structureless with a sand-silt fraction consisting almost exclusively of quartz, a low nutrient-holding capacity, and a high bulk density and are deficient in N, P and K (Mitsuchi *et al*. 1986). They are low in organic matter and have a closely packed topsoil over a packed subsoil. As such, they can be waterlogged for long periods during the wet season (2–3 months) and then dry out quickly during the dry season forming a hard pan (Ragland and Boonpuckdee 1986).

Currently, only 2 grass species are suitable for wet soils in Thailand. They are plicatulum (*Paspalum plicatulum*) and para grass (*Brachiaria mutica*). Both species grow well in wet sites during the wet season but perform poorly over the dry season. Plicatulum is a low quality grass and is not eaten readily by dairy cows. Para grass must be planted vegetatively which limits its expansion. It is very palatable, and is often grazed out during the dry season. Ruzi grass (*Brachiaria ruziziensis*), the most widely grown grass in Thailand, and guinea grass do not grow well in waterlogged sites.

With small farm sizes, farmers prefer a cut-and-carry system rather than grazing. They need pasture species that grow quickly and produce high dry matter yields. The pastures must start producing forage within 8–10 weeks of establishment and then be cut every 30–45 days during the wet season. Many pastures do not get sufficient time to establish or to recover following defoliation and receive little or no fertiliser. During the dry season, many pastures are over-grazed

Research was initiated in 1995 to evaluate a range of grass and legume species for dairy farms located on former rice paddy lowland in north-east Thailand which is seasonally waterlogged for up to 3 months and seasonally dry for 4–5 months. This paper presents preliminary evaluation data from these trials.

Materials and methods

Trial 1. Evaluation of grasses and legumes

These trials were conducted at 2 sites in Ubon Ratchathani province (15°N); on the Ubon Ratchathani University Farm (UBU) and on the Ubon Ratchathani Animal Nutrition Station (UBS), Department of Livestock Development. A third site was also initially sown at the Yasothon Animal Nutrition Station, 70 km north, but the site was severely flooded 7 weeks after sowing, destroying the plots; no data were collected.

Annual rainfall was recorded 1 km from the UBU site and 6 km from the UBS site (Table 1). The soil at UBU is classified as a sandy low humic gley soil (Roi-et soil series) mixed with a grey podzolic soil (Khorat soil series) and usually is waterlogged from July to early October. The soil at UBS is a grey podzolic soil which is better drained and not subject to waterlogging. Soil tests were taken in June 1995, 1 month before sowing. Both soils were acid (pH 4.6), and low in organic matter (0.5–0.7%), N (0.02–0.03%), P (3–13 ppm) and K (20–50ppm). The site at UBU was formerly rice paddy land but prior to cultivation had been in native grasses (mainly *Eremochloa* spp.) for 6 years. The site at UBS was an established signal grass (*Brachiaria decumbens*) field used for cut-and-carry forage.

Seed of 12 grasses and 8 legumes (Table 2) was hand broadcast at 4 kg/ha on to 5 × 5 m plots in separate randomised blocks with 3 replications. Field management details are presented in Table 3. Legume seed was inoculated with the respective commercial inoculant before sowing. At sowing, fertiliser was applied and the seed and fertiliser raked into the soil (Table 3). On July 19, 1996, the plots of purple pigeon grass (*Setaria incrassata*), which had died out, were replaced with tillers of *Paspalum atratum* BRA009610 at UBS and *Paspalum plicatulum* at UBU, planted in 30 × 30 cm grid spacings.

Establishment counts were made in eight 0.25 m^2 quadrats per plot, 6 weeks after sowing.

Table 1. Rainfall for the trial sites at Ubon Ratchathani University (UBU), Ubon Ratchathani Animal Nutrition Station (UBS) and Yasothon Animal Nutrition Station (YNS).

Month and season	Rainfall (mm)								
	1995–96			1996–97			1997–98		
	UBU	UBS	YNS	UBU	UBS	YNS	UBU	UBS	YNS
May	230	288	70	125	133	110	150	194	47
June	168	199	210	187	160	78	352	312	314
July	323	250	257	132	161	98	399	453	432
August	134	108	244	162	161	161	324	214	490
September	298	193	183	468	544	381	239	157	118
October	131	131	77	141	142	117	107	86	57
Wet season	1284	1169	1041	1215	1301	945	1571	1416	1458
November	38	34	44	123	59	44	0	0	0
December	2	0	0	0	0	0	0	0	0
January	0	0	0	2	1	0	0	0	3
February	0	1	0	2	7	47	43	58	22
March	12	3	0	71	40	41	0	0	0
April	203	106	141	52	82	99	60	75	27
Dry season	255	144	185	250	189	231	103	133	52
Annual total	1539	1313	1226	1465	1490	1176	1674	1549	1510

Table 2. Plant populations (6 weeks after sowing) of grass and legume species at Ubon Ratchathani University (UBU) and Ubon Ratchathani Animal Nutrition Station (UBS).

Scientific name	Common name & cultivar	Plant no./m^2	
		UBU	UBS
Grasses			
Brachiaria ruziziensis	Ruzi grass	19.5	15.5
Brachiaria humidicola	Koronivia grass cv. Tully	7.0	4.0
Brachiaria decumbens	Signal grass cv. Basilisk	23.2	17.3
Setaria sphacelata var. *splendida*	Setaria cv. Splenda	14.7	35.0
Setaria sphacelata var. *sericea*	Setaria cv. Solander	8.5	16.3
Cynodon dactylon	Bermuda grass	37.7	18.0
Panicum coloratum var. *marikariense*	Makarikari grass cv. Bambatsi	18.8	9.3
Setaria incrassata	Purple pigeon grass cv. Inverell	2.7	7.2
Chloris gayana	Rhodes grass cv. Fine-cut	30.0	53.5
Paspalum dilatatum	Dallis grass cv. Raki	26.0	26.0
Paspalum atratum		34.5	—
Paspalum plicatulum	Plicatulum	—	26.0
Digitaria milanjiana	Digit grass cv. Jarra	11.2	31.0
	LSD ($P < 0.05$)	20.1	16.4
Legumes			
Stylosanthes hamata	Caribbean stylo cv. Verano	42.2	39.7
Aeschynomene americana	American jointvetch cv. Lee	52.0	58.8
Calopogonium mucunoides	Calopo	25.5	23.8
Centrosema pascuorum	Centurion cv. Cavalcade	14.8	14.3
Macroptilium gracile	Llanos macro cv. Maldonado	58.0	48.0
Stylosanthes guianensis	Stylo cv. Graham	35.3	18.3
Arachis pintoi	Pinto peanut cv. Amarillo	1.8	2.3
Centrosema pubescens	Centro cv. Common	6.7	5.7
	LSD ($P < 0.05$)	14.0	14.0

Table 3. Details of field management.

	Trial 1	Trial 2	Trial 3
Field culitivation	Ploughing × 2, discing × 1, and rotary hoeing × 1	Ploughing × 2, discing × 1, and rotary hoeing × 1	Ploughing × 2, discing × 1, and rotary hoeing × 1
Plot size	5 × 5 m	5 × 5 m	5 × 5 m
Sowing date	July 20, 1995 UBU July 24, 1995 UBS	May 13, 1996 UBU May 14, 1996 YNS	May 13, 1996 UBU
No. of sampling quadrats/plot	Six 0.25m^2	Four 0.25m^2	Four 0.25m^2
Sampling cuts			
First wet season	Oct 16, 1995	Sep 3 and Nov 4, 1996	Aug 28 and Oct 28, 1996
First dry season	Apr 19, 1996	Jan 28 and Apr 23, 1997	Feb 4 and Apr 28, 1997
Second wet season	June 19, Aug 14 and Oct 18, 1997	June 10, July 28, Sep 15 and Oct 31, 1997	June 12, July 25, Sep 10 and Nov 5, 1997
Second dry season	Dec 23, 1996 and Apr 22, 1997	Jan 26 and Apr 20, 1998	Jan 6 and Apr 30, 1998
Third wet season	June 9, Jul 28, Sep 15 and Oct 30, 1997	—	—
Third dry season	Jan 26 and Apr 22, 1998		
Fertiliser (kg/ha)			
At sowing	P 10, S 20, K 50, N 25	P 10, S 20, K 50	P 10, S 20, K 50
After each cut	P 20, S 20, K 50, N 40	P 20, S 20, K 50, N 40	P 20, S 20, K 50, N 40

Dry matter cuts were taken at intervals for 3 years as detailed in Table 3. At each cut, six 0.25 m^2 quadrats were harvested and then hand sorted into sown species and weeds (all other vegetation). A 200 g subsample of each sown species was dried at 70°C for 48 hours and dry weight recorded. This dried subsample was bulked across replicates and then 2 samples per treatment were analysed for total N in order to calculate crude protein levels (%N × 6.25).

After each sampling, all plots were cut with hand mowers, the mown material removed and fertiliser applied (Table 3).

Trial 2. Evaluation of grasses with and without llanos macro

Trial 2 was sown at 2 sites; at the University (UBU) and at the Yasothon Animal Nutrition Station (YNS), 70 km from the University. The UBU site was adjacent to the site of the previous trial on identical soils with similar, low fertility. The site at YNS was on former rice paddy land that had been in plicatulum seed crops for several years. The soils at YNS are grey podzolic soils which are waterlogged from August to October and often are flooded. A soil test taken from the YNS soil in May 1996 showed a pH of 4.9, organic matter (OM) of 0.5%, total N of 0.006%, P of 11 ppm, sulphur (S) of 7.5 ppm and K of 2.5 ppm. Annual rainfall was recorded for the University 1 km from the UBU site and at YNS on the station 100 m from the YNS site (Table 1).

Five grasses (Ruzi, signal, plicatulum, Splenda setaria and *P. atratum*) were sown at 6 kg/ha in randomised split plots, measuring 5 × 5 m, with and without llanos macro (*Macroptilium gracile* cv. Maldonado), in 3 replications (Table 3). Field management is detailed in Table 3.

Llanos macro established quickly and threatened to smother the grasses. On July 24, 1996, the trial was topped to 10 cm height and the cut material removed to reduce legume dominance.

At each sampling, cut material was hand sorted into sown grasses and legumes. Weeds were discarded. A 200 g subsample was dried as in Trial 1 but analysed only for total N in the second wet season.

After each sampling, the plots were cut with hand mowers, the mown material removed and fertiliser applied (Table 3).

Trial 3. Evaluation of llanos macro with and without grasses

Llanos macro was evaluated further in a small trial at UBU in 1996 and 1997. The trial site was adjacent to the previous trials and land preparation was the same.

The trial consisted of 5 treatment mixtures of llanos macro (llanos macro alone; with signal grass; with *P. atratum*; with plicatulum; and with Splenda setaria) sown in a randomised block design with 4 replications. Seed of all species was hand broadcast at 6 kg/ha, fertiliser applied and the seed and fertiliser raked into the soil (Table 3).

All plots were topped to a height of 10 cm on July 26 to prevent llanos macro from smothering the grasses.

The times of dry matter sampling cuts and the amounts of fertiliser applied after each cut are detailed in Table 3. At each sampling cut, cut material was hand sorted into sown grasses and llanos macro. A 200 g subsample was dried as in previous trials to calculate dry matter and total N.

Data from all trials were analysed using the IRRISTAT programme from IRRI. Crude protein data were not statistically analysed because samples were bulked across replicates.

Results

Rainfall

Wet season rainfall was good at all sites, particularly in the last wet season (Table 1) when over 1400 mm fell in the region. The low lying UBU and YNS sites became waterlogged towards the end of each wet season (August and September) but the higher, well drained UBS site did not. Some rain fell during each dry season but the 1997–98 dry season was particularly dry, with no rain falling from November to January at all sites.

Trial 1. Evaluation of grasses and legumes

Grasses. Establishment of most species was good by 6 weeks after sowing (Table 2), except for koronivia grass, purple pigeon grass and Solander setaria at UBU and makarikari grass at UBS. Ruzi produced the most dry matter in the first wet season at UBU followed by signal, Splenda setaria and *P. atratum* and these grasses were also the most productive during the first dry season (Table 4). At UBS, fine-cut rhodes was the most productive in the first wet season followed by ruzi, signal and plicatulum (Table 4). Except for ruzi, these same grasses produced well in the first dry season at UBS, together with koronivia grass.

In the second wet season at UBU, *P. atratum* produced 22.6 t/ha DM in 6 months, significantly more than for any other grass (Table 4). Ruzi, signal, Solander setaria, plicatulum and Jarra digit grass produced more than 20.0 t/ha DM during the second wet season at UBS. In the second dry season, there were no differences between species at UBU, but at UBS, signal grass and *P. atratum* produced significantly more DM than all except koronivia grass and plicatulum.

In the third wet season at UBU, *P. atratum*, plicatulum, Jarra digit grass, Splenda setaria and koronivia grass produced more than 12.0 t/ha DM in 6 months (Table 4). Grasses were higher yielding at UBS, with Jarra digit grass producing 27.0 t/ha DM followed by *P. atratum*. During the dry season at UBU, koronivia grass and *P. atratum* produced more than 7.0 t/ha DM followed by the two setaria cultivars, plicatulum and ruzi grass (Table 4). Koronivia grass was also the highest producing grass during the third dry season at UBS, followed by plicatulum, signal grass and Jarra digit grass.

Legumes. All legumes except centro and Amarillo pinto peanut had established well with a good plant population by 6 weeks after sowing (Table 2). Llanos macro was the most productive legume during the first wet season at both sites, producing more than 2.0 t/ha DM in 12 weeks (Table 4), but at UBS, Lee American jointvetch and Verano stylo produced similar yields. Graham stylo outyielded all other species in the dry season at UBU, but at UBS, the legumes had disappeared by the time of cutting at the end of the dry season. Amarillo pinto peanut disappeared from both sites and did not grow back at all during the following 2 years.

The legumes at UBS grew back from fallen seed in the second wet season, with Verano stylo producing nearly 10.0 t/ha DM in 6 months, which was 2.0 t/ha more than yields of the next best legumes, Lee American jointvetch and Cavalcade centurion (Table 4). At UBU, both Verano stylo and Graham stylo produced more than 9.0 t/ha DM in the second wet season. In the second and third dry seasons, legumes disappeared before any material could be collected.

During the third wet season, many of the legumes regrew from fallen seed and by the time of cutting in October 1997, Graham stylo had produced in excess of 10.0 t/ha DM at UBU and Verano stylo over 5.0 t/ha DM at both sites (Table 4).

Table 4. Dry matter yields of grass and legume species at Ubon Ratchathani University (UBU) and Ubon Ratchathani Animal Nutrition Station (UBS) (Trial 1).

	1995–96				1996–97				1997–98			
	Wet		Dry		Wet		Dry		Wet		Dry	
	UBU	UBS	UBU	UBS	UBU	UBS	UBU	UBS	UBU	UBS	UBU	UBS
a) Grass species					(t/ha)							
Ruzi grass	2.56	2.13	2.60	0.75	16.64	24.75	3.73	5.50	10.20	21.73	5.14	2.24
Koronivia grass cv. Tully	0.23	0.31	1.12	1.99	12.59	19.24	4.62	7.64	12.57	22.27	7.36	4.45
Signal grass cv. Basilisk	1.72	1.39	2.73	2.21	17.27	21.66	6.01	10.34	7.75	19.09	2.97	3.76
Splenda setaria	1.68	0.95	2.26	1.24	16.68	19.75	5.44	6.35	15.08	18.74	5.88	—
Solander setaria	0.30	0.23	1.61	0.58	11.59	21.63	4.74	4.99	9.41	—	5.22	—
Bermuda grass	—	0.10	0.04	0.26	0.44	6.86	—	4.80	—	10.69	—	1.84
Bambatsi makarikari grass	0.09	0.08	0.54	0.28	0.30	13.33	—	—	—	—	—	—
Purple pigeon grass	—	0.18	—	0.34	—	3.82	—	—	—	—	—	—
Fine—cut rhodes grass	0.32	2.41	0.45	1.67	0.62	13.95	—	2.58	—	—	—	—
Raki paspalum	0.32	0.60	0.74	0.75	9.30	11.12	4.12	3.73	11.02	—	3.01	—
Paspalum atratum	1.94	—	3.14	—	22.67	—	4.23	9.99	16.83	25.60	7.27	3.12
Plicatulum	—	1.43	—	1.48	—	24.14	4.01	7.51	14.89	22.89	5.92	3.81
Jarra digit grass	0.36	0.78	1.16	1.04	15.12	22.52	4.79	7.19	15.97	27.09	3.85	3.33
LSD (P < 0.05)	1.14	0.70	1.03	0.83	4.20	5.61	NS	2.70	5.34	4.48	2.34	0.98
b) Legume species												
Verano stylo	0.92	1.92	0.35	—	9.05	9.95	—	—	5.77	5.80	—	—
Lee American jointvetch	0.61	2.22	0.23	—	4.85	7.75	—	—	3.44	1.43	—	—
Calopo	0.71	1.57	0.47	—	6.64	5.62	—	—	5.00	3.67	—	—
Cavalcade centurion	0.80	1.23	0.09	—	6.48	7.25	—	—	3.63	1.87	—	—
Llanos macro cv. Maldonado	2.64	2.03	0.02	—	3.80	6.85	—	—	2.03	1.27	—	—
Graham perennial stylo	0.41	0.99	1.66	—	9.82	3.95	—	—	10.41	—	—	—
Amarillo pinto peanut	0.04	0.05	—	—	—	—	—	—	—	—	—	—
Centro	0.11	0.19	0.24	—	0.42	—	—	—	1.70	—	—	—
LSD (P < 0.05)	0.65	0.89	0.70	—	0.65	2.34	—	—	5.55	1.42	—	—

Table 5. Dry matter production from grass and grass-llanos macro swards in the first wet season after planting and the subsequent dry season at Ubon Ratchathani University (UBU) and Yasothon Animal Nutrition Station (YNS) (Trial 2).

Treatment	Wet (1996)			(Dry (1996–97)		
	Grass only	Grass + llanos macro (% llanos)	Sig.[2]	Grass only	Grass + llanos macro (% llanos)	Sig.
			(t/ha) UBU			
P. atratum	4.31ab[1]	7.85a (73)	*	6.62a	7.20a (46)	ns
Ruzi grass	7.57a	8.96a (50)	ns	5.70a	6.24a (39)	ns
Plicatulum	2.27b	6.13a (70)	*	3.81a	5.90a (43)	ns
Signal grass	7.40a	8.87a (32)	ns	6.75a	6.94a (11)	ns
Splenda setaria	5.81ab	8.91a (51)	ns	4.01a	6.81a (33)	ns
Mean	5.47	8.14	**	5.38	6.62	ns
			YNS			
P. atratum	4.73ab	5.59b (79)	ns	6.30a	4.86a (3)	ns
Ruzi grass	3.16b	6.47ab (70)	*	3.76a	4.85a (1)	ns
Plicatulum	3.85ab	7.90ab (59)	**	4.70a	5.70a (3)	ns
Signal grass	5.30ab	5.69b (73)	ns	5.25a	5.52a (1)	ns
Splenda setaria	7.27a	9.40a (57)	ns	6.05a	7.08a (3)	ns
Mean	4.86	7.01	**	5.21	5.60	ns

[1] Within columns and within sites, values followed by different letters are significantly different (P < 0.05) by Duncan's Multiple Range Test.

[2] Within rows and within seasons, the significance of differences between means is indicated by ns, * (P < 0.05) and ** (P < 0.01).

Trial 2. Evaluation of grasses with and without llanos macro

In the first wet season, grass swards with llanos macro produced significantly more dry matter than grass-only swards at UBU and YNS (Table 5). In the mixed swards, llanos macro contributed on average, 67% and 55% of sward dry matter production at UBU and YNS, respectively. In the grass swards in the first wet season, the most productive grasses were ruzi and signal at UBU and Splenda setaria at YNS (Table 5).

Table 6. Dry matter production from grass-llanos macro swards in the second wet season after planting and the second dry season at Ubon Ratchathani University (UBU) and Yasothon Animal Nutrition Station (YNS) (Trial 2).

Treatment	Grass + llanos macro (% llanos)			
	UBU		YNS	
	Wet (1997)	Dry (1997–98)	Wet (1997)	Dry (1997–98)
	(t/ha)			
P. atratum	23.75a[1] (7)	6.87a	16.54a	3.33a
Ruzi grass	11.56c (13)	2.40c	8.12b	1.49b
Plicatulum	16.14bc (16)	4.40b	11.08b	2.16b
Signal grass	11.80c (14)	3.77bc	9.60b	2.00b
Splenda setaria	17.24b (12)	4.86b	10.94b	3.29a
Mean	16.10	4.46	11.26	2.45

[1] Within columns, values followed by different letters are significantly different (P < 0.05) by Duncan's Multiple Range Test.

In the first dry season, there were no significant differences between grass species and no significant differences between grass-only and grass-llanos macro swards at both sites (Table 5). Llanos macro continued to grow well in mixed swards at UBU during the dry season, but at YNS, it had disappeared by the time of the last dry season cut in April 1997.

In the second wet and dry seasons, there were no significant differences between grass-only and mixed swards, so only data from mixed swards are presented (Table 6). *Paspalum atratum* produced significantly more dry matter than other grass species in both seasons at UBU and in the second wet season at YNS. Both Splenda setaria and *P. atratum* produced more dry matter than other species at YNS in the second dry season (Table 6).

Trial 3. Evaluation of llanos macro with and without grasses

Legume. Llanos macro grew vigorously in the first wet season, contributing 40–56% of total mixed sward dry matter production (Table 7). Pure swards of llanos macro in the first dry

Table 7. Dry matter production from llanos macro in pure swards and mixed grass swards at Ubon Ratchathani University.

	No grass	*Paspalum atratum*	Plicatulum	Splenda setaria	Signal grass	LSD (P < 0.05)
			(t/ha) First wet season 1996			
Llanos macro	5.40	4.16	2.91	3.23	4.02	1.71
Grass	—	3.49	2.25	5.01	5.34	1.82
Total	5.49	7.65	5.15	8.24	9.36	1.92
			First dry season 1996–97			
Llanos macro	2.14	0.95	0.32	0.93	0.30	0.67
Grass	—	5.84	5.18	6.67	10.32	2.88
Total	2.14	6.79	5.50	7.60	10.62	2.40
			Second wet season 1997			
Llanos macro	2.04	0.20	0.02	0.17	1.81	1.48
Grass	—	26.30	18.80	18.79	15.16	2.83
Total	2.04	26.50	18.82	18.96	15.97	2.62
			Second dry season 1997–98			
Llanos macro	—	—	—	—	—	
Grass	—	5.57	3.92	5.47	4.03	1.10

season produced significantly more dry matter than llanos macro growing in mixed swards.

In the second wet season, llanos macro contributed negligible amounts of dry matter in swards of *P. atratum*, plicatulum and setaria, but about 2.0 t/ha in pure swards and in signal grass swards (Table 7). Llanos macro died out very early in the second dry season before any cuts were made.

Grasses. Signal grass and setaria produced more dry matter than plicatulum and *P. atratum* in the first wet season (Table 7). Signal grass averaged 75% more growth than other grasses in the first dry season, producing over 10.0 t/ha DM.

However, in the second wet season, *P. atratum* was the best grass, producing more than 26.0 t/ha DM in 6 months, which was, on average, 50% better than the other 3 grass species (Table 7). Both *P. atratum* and setaria grew well in the second dry season.

Crude protein concentration

Crude protein in all grass species at UBU was below 7% in the wet season and below 4.5% in the dry season (Table 8). These levels were lower than levels in similar species at UBS and YNS. Dry season crude protein levels were particularly low at UBU in Trial 2 with plicatulum and *P. atratum* below 3%.

The legumes at UBU were, on average, about 7% lower in crude protein than similar species at UBS (Table 9). No material could be collected to determine legume crude protein concentration in the dry season.

Table 9. Average wet season crude protein percentage of legume species in Trial 1 at Ubon Ratchathani University (UBU), and Ubon Animal Nutrition Station (UBS).

Species	UBU	UBS
Verano	12.9	17.4
Lee	16.6	20.1
Calopo	11.0	17.9
Cavalcade	10.3	17.9
Llanos macro	8.8	18.5
Graham stylo	11.8	17.4
Centro	9.3	15.6

Discussion

This study has identified a number of grass species which show distinct promise on these seasonally waterlogged soils.

P. atratum, ruzi grass and Splenda setaria were the best establishing grasses in the first wet season on lowland wet sites (UBU and YNS). On the better drained site at UBS, Fine-cut rhodes grass was quick to establish but failed to persist after 2 years.

In the second and third wet seasons after establishment, *P. atratum* was the highest producing grass in all trials on the wet lowland sites, producing more than 20 t/ha DM when fertilised. These yields were substantially higher than *P. atratum* yields in Florida where, with similar levels of fertiliser and a longer growing season, cv. Suetre produced up to 14.8 t/ha DM

Table 8. Average seasonal crude protein percentage of grass species at Ubon Ratchathani University (UBU), Ubon Animal Nutrition Station (UBS) and Yasothon Animal Nutrition Station (YNS).

Species	Wet season				Dry season			
	Trial 1		Trial 2		Trial 1		Trial 2	
	UBU	UBS	UBU	YNS	UBU	UBS	UBU	YNS
Ruzi	5.4	6.4	4.6	5.9	4.1	6.3	4.9	6.0
Koronivia	4.9	7.0	—	—	3.7	4.7	—	—
Signal	5.6	7.5	5.1	6.0	4.0	5.1	3.9	5.6
Splenda setaria	5.9	6.9	5.0	6.0	4.4	5.9	3.5	3.8
Solander setaria	5.6	—	—	—	4.2	5.9	—	—
Bermuda	6.7	8.6	—	—	—	6.8	—	—
Dallis	6.1	—	—	—	4.4	5.0	—	—
Plicatulum	4.8	6.3	4.4	4.7	4.2	4.3	2.7	3.9
P. atratum	4.4	4.8	4.5	4.6	3.4	3.9	2.6	3.9
Digit	5.3	6.6	—	—	3.7	5.0	—	—

(Kalmbacher *et al*. 1997a). Differences in yield are probably due to higher rainfall and temperatures in Thailand. *P. atratum* continued to produce between 4 and 7 t/ha DM in the dry season, which at least equalled the production of other grass species.

Ruzi grass established very well in the first year, but on wet sites in following seasons it yielded significantly less than *P. atratum*. Splenda setaria and plicatulum grew well in most trials but were not as consistent in producing high yields as *P. atratum*. Jarra digit grass and koronivia grass were slow to establish but with time, these 2 rhizomatous species became dense and spread vigorously into surrounding plots, particularly on the better drained site at UBS. Jarra digit grass appears to be a very aggressive grass and, on sites that are not too waterlogged, forms a very dense and productive sward. Signal grass grew well on drier sites, particularly during the dry season if it was not weakened by wet season waterlogging. In 2 trials, it produced more than 10 t/ha DM during the 6-month dry season.

Legumes still remain a problem on waterlogged soils which dry out in the dry season and we are unable to recommend any legume for such sites to dairy farmers. Graham perennial stylo, Verano stylo and calopo grew well on the waterlogged site at UBU during the wet season, with Graham the best performing. After the second wet season, none of these legumes produced dry season forage. Llanos macro was productive in the first wet season but in mixed swards did not persist after 2 years. On waterlogged sites in Australia (Ross and Cameron 1991), llanos macro in pure swards persisted and spread into surrounding plots, but in these trials cutting was only once a year at the end of the dry season. In our trials we usually cut 4 times during the wet season and twice in the dry season. Llanos macro appears to require careful management in order to grow well in the wet season. It must then be allowed to seed over the dry season to re-establish the following wet season.

Despite good levels of fertiliser, crude protein levels of all species, even the legumes, were low on these infertile waterlogged soils. This is of some concern in that dairy farmers would apply only about a quarter of the fertiliser applied in these trials. *P. atratum*, in particular, had low levels of crude protein throughout the year which were lower than levels found in Florida (Kalmbacher *et al*. 1997b). Farmers growing *P. atratum* in Thailand, however, have been very pleased with its production because it grows so much better than ruzi grass on lowland sites in both the wet and dry seasons. They are not concerned about low protein levels as they would feed some protein concentrate to their dairy cows, regardless of the grass protein concentration.

Generally, smallholder dairy farmers in north-east Thailand find it difficult to grow and manage pastures for several years. Many do not have a history of livestock farming as they were formerly rice farmers who may or may not have reared water buffalo for draft. The ecosystem of very wet and then very dry conditions adds to the difficulty of pasture persistence, productivity and sustainability. From these preliminary evaluation trials, *P. atratum* appears to be well suited for smallholder dairy farmers growing grass on lowland seasonally wet areas. It produces a large amount of dry matter over the wet season and continues to grow in the dry season, but not on deep sandy soils (Kalmbacher *et al*. 1997c). It also remains very leafy and, when frequently cut or frequently grazed, will not produce seed heads. *P. atratum* BRA 009610 has been released in Thailand by Ubon Ratchathani University as cv. Ubon.

Acknowledgements

We thank the Thailand Research Fund for providing financial support to this research programme, the Faculty of Agriculture, Ubon Ratchathani University for research facilities and the Department of Livestock Development for research sites and assistance on their field stations. We also thank Mrs Chaisang Phaikaew for advice during the programme and Mr Sukri Saipraset for technical assistance. We also thank Dr Werner Stur, CIAT/IRRI, for providing us with the initial 100 g of *P. atratum* seed.

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(Received for publication August 12, 1998; accepted April 29, 1999)