Evaluation of forage legumes and grasses on seasonally waterlogged sites in north-east Thailand

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Abstract

Seven legumes sown in pure swards and 7 grasses sown with legumes and fertilised with N were evaluated in a series of trials at 7 low lying infertile sites in north-east Thailand over 2–3 years from 1997–2000. All sites have an average annual rainfall of 1400 mm.

The highest legume yield in pure swards was in the year of sowing from *Aeschynomene americana* cv. Lee, which produced over 14 t/ha DM at one site. All legumes failed to persist beyond the second wet season under cutting. *Stylosanthes guianensis* cv. Tha Phra (CIAT 184) showed some promise as a legume at some sites that were not deeply waterlogged but only in a few places was it able to persist into the second dry season. No legumes performed well enough to be recommended for such sites under the existing management system.

The best grasses on deeply waterlogged sites were *Paspalum atratum* cv. Ubon, *P. plicatulum* (common Thailand type) and *Setaria sphacelata* var. *splendida* cv. Splenda. These 3 grasses performed well at all sites and were the most consistent in terms of persistence and yield. On less waterlogged sites, *Panicum maximum* cv. Purple was very productive, producing in excess of 30 t/ha DM in the second 6-month wet season at 2 sites. *Brachiaria ruziziensis* (common Thailand type), *B. decumbens* cv. Basilisk, and *Digitaria milanjiana* cv. Jarra grew well only on sites that did not become inundated with water. No legumes were able to persist in the nitrogen-fertilised (100–120 kg/ha N) grass swards beyond the second wet season.

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Introduction

Preliminary evaluation trials were conducted from 1995–1998 on tropical pasture grasses and pasture legumes for seasonally wet and seasonally dry lowland pastures (1500 mm average annual rainfall) on infertile soils in north-east Thailand (Hare *et al.* 1999a). *Paspalum atratum* cv. Ubon was consistently the best grass, producing, on average, more than 20 t/ha DM in a 6-month wet season. *Setaria sphacelata* var. *splendida* cv. Splenda and *P. plicatulum* also grew well and *Digitaria milanjiana* cv. Jarra was very productive on better drained soils.

Legumes, however, did not persist on soils which were waterlogged for 3–5 months and then dry for several months and Hare *et al.* (1999a) were unable to recommend any legumes to farmers. *Stylosanthes guianensis* cv. Graham, *S. hamata* cv. Verano, *Calopogonium mucunoides* (common type) and *Macroptilium gracile* cv. Maldonado (Llanos macro) grew well in the first year but failed to persist after the second wet season. In further experiments, none of the legumes sown with *P. atratum* cv. Ubon or *Brachiaria mutica* persisted after the second wet season on low lying sites (Hare *et al.* 1999b).

As these evaluations were carried out on 3 sites only (Hare *et al.*1999a; 1999b), we considered it necessary to conduct further small plot trials on several low lying sites to confirm that *P. atratum* cv. Ubon was indeed the best grass and to attempt to identify a suitable legume for these sites. In our first series of trials, Graham stylo showed promise, but in 1997 was devastated with anthracnose. At this time, *S. guianensis* CIAT 184, which was resistant to anthracnose, was growing well on well drained sites in Thailand following its success in South America

(Amezquita *et al.* 1991), China (Guodao and Kerridge 1997) and parts of south-east Asia (Ibrahim *et al.* 1997). The Division of Animal Nutrition, Department of Livestock Development, had renamed CIAT 184 as Tha Phra stylo and were producing seed. However, there had been no evaluation of Tha Phra stylo on low lying sites.

The current research involved the following 3 experiments: evaluation of 7 grasses sown with legumes at 3 sites for productivity and persistence; evaluation of Tha Phra stylo in association with 7 grasses at 5 sites; and evaluation of 7 legumes for productivity and persistence at 3 sites.

Materials and methods

Trial 1 — Evaluation of grasses sown with legumes

This study was conducted at 3 sites in north-east Thailand (15–16°N): on the Ubon Ratchathani University Farm (UBU); at the Mukdahan Animal Nutrition Station (MUK); and in a village in Det Udom district of Ubon Ratchathani Province (DET). All sites are usually very wet from August–October with the site at DET deeply waterlogged during this period. The soils at UBU and DET are classified as sandy low humic gley soils (Roi-et soil series). The soil at MUK is also a low humic gley soil (Renu soil series) but contains less sand than the Roi-et soils. Prior to commencing the study, the site at UBU had been under native grasses (*Eremochloa ciliaris* and *Panicum repens*) for 7 years following long-term paddy rice cultivation. The site at MUK had been planted to various tropical grass pastures for 20 years and the site at DET had been cultivated for annual paddy rice production for generations by village farmers. Soil tests were conducted on samples taken in May 1997 just prior to sowing the experimental pastures. Annual rainfall was recorded 1 km from the UBU site, 500 m from the MUK site and 15 km from the DET site.

Seven grasses [*Paspalum plicatulum* (common Thailand type), *P. atratum* cv. Ubon, *Brachiaria ruziziensis* (common Thailand type), *B. decumbens* cv. Basilisk, *Setaria sphacelata* var. *splendida* cv. Splenda, *Digitaria milanjiana* cv. Jarra and *Panicum maximum* cv. Purple] were sown at 18 kg/ha in a randomised block design with 4 replications. High sowing rates are commonly used by farmers and researchers in Thailand to ensure an adequate stand as insurance against seed-eating ants, erratic early wet season rainfall poor soil preparation. Four legumes [*Stylosanthes hamata* cv. Verano, *Macroptilium gracile* cv. Maldonado (Llanos macro), *Aeschynomene americana* cv. Lee (American jointvetch) and *Centrosema pascuorum* cv. Cavalcade] were each sown at 6 kg/ha with each grass species. Each plot measured 10 × 5 m.

The species were hand broadcast into well cultivated seed beds at MUK on May 7, at UBU on May 12 and at DET on May 14, 1997 and the seed lightly surface raked into the soil. The plots were fertilised at sowing with N (20 kg/ha), K (50 kg/ha), P (20 kg/ha) and S (20 kg/ha).

Plant counts were made in five 0.25 m^2 quadrats per plot, 6 weeks after sowing. Dry matter cuts were taken from five 0.25 m^2 quadrats per plot cut 5 cm from ground level, 3–4 times each wet season (May–October) and 2–3 times each dry season (November–April). The study was terminated at the end of April 2000.

At each cut, the samples were sorted into grass and legume and a 200 g subsample of each species from each plot was dried at 70°C for 48 hours and dry weight recorded. After sampling, all plots were cut to about 5 cm above ground level, the forage removed and the plots fertilised with N (20 kg/ha), K (50 kg/ha), P (20 kg/ha) and S (20 kg/ha). The amounts applied were based on experience and research (Hare *et al.* 1999c). Lesser amounts can result in plant deficiencies, especially in grasses, due to leaching of elements from these sandy soils. The average CEC on these soils is 2.3 meq/100 g, S 2–5 ppm and K 20–40 ppm.

Trial 2 — Evaluation of grasses sown with Tha Phra stylo

This study was conducted at 5 sites in north-east Thailand (15–16°N): on the Ubon Ratchathani University Farm (UBU); Yasothon Animal Nutrition Station (YNS); Yasothon Agricultural Technology College Farm (YAC); Sisaket Agricultural Technology College Farm (SAC); and the Ubon Ratchathani Agricultural Technology College Farm (UAC). Soils at all sites are classified as sandy low humic gley soils (Roi-et soil series) and are usually very wet from August–October with the site at SAC deeply waterlogged during this period. All sites, at some time in the past, had been used for paddy rice cultivation. Prior to commencing the study, the site at UBU had been under native grasses (*Eremochloa ciliaris* and *Panicum* *repens*) for 8 years, the site at YNS under *P. plicatulum* pastures for 5 years, the site at SAC under paddy rice and the sites at UAC and YAC under a mixture of *P. plicatulum* and *Mimosa pudica*.

Soil tests were conducted on samples taken in May 1998, just prior to sowing the pastures. Annual rainfall was recorded as in Trial 1 for UBU, 100 m from the YNS site, 200 m from the SAC site and 15 km from the UAC site. No rainfall was recorded near the YAC site but, as it was only 15 km from the YNS site, data from this site were used.

Seven grasses (*P. plicatulum, P. atratum* cv. Ubon, *B. ruziziensis, B. decumbens* cv. Basilisk, *S. sphacelata* var. *splendida* cv. Splenda, *D. milanjiana* cv. Jarra and *P. maximum* cv. Purple) were sown at 12 kg/ha together with *S. guianensis* cv. Tha Phra (CIAT 184) at 6 kg/ha in a randomised block design with 4 replications. Each plot measured 5 × 5 m.

The species were hand broadcast into well cultivated seed beds at UBU on May 7, at YNS and YAC on May 13, at SAC on May 14 and at UAC on May 15, 1998 and the seed lightly surface raked into the soil. The plots were fertilised at sowing with N (20 kg/ha), K (25 kg/ha), P (10 kg/ha) and S (10 kg/ha).

Plant counts were made in four $0.25m^2$ quadrats per plot, 6 weeks after sowing. Dry matter cuts were taken from four $0.25m^2$ quadrats at 5 cm from ground level in each plot 3–4 times each wet season and 2–3 times each dry season.

Cattle grazed plots at UAC before sampling in October 1998, so, on October 27, 1998, all plots were trimmed to 5 cm above ground level and fertiliser applied. At YAC, the trial was terminated after sampling in September 1999 due to uncontrolled grazing and, at SAC and UAC, observations ceased in October 1999 following repeated cutting by village farmers. At other sites, the trial was terminated at the end of April 2000.

At each sampling, the samples were sorted into grass and Tha Phra stylo and a 200 g subsample of each species was dried as in Trial 1. After each sampling, all plots were topped as described for Trial 1 and fertilised with the same amounts spread at sowing.

Trial 3 — Evaluation of legumes

This study was conducted at 3 sites (UBU, YNS and YAC) adjacent to Trial 2. Soil tests and rainfall were the same as in Trial 2.

Seven legumes (*Stylosanthes hamata* cv. Verano, *S. guianensis* cv. Tha Phra, *Centrosema pascuorum* cv. Cavalcade, *Calopogonium mucunoides*, *Macroptilium gracile* cv. Maldonado, *Pueraria phaseoloides* and *Aeschynomene americana* cv. Lee) were sown at 12 kg/ha in a randomised block design with 4 replications. Each plot measured 5 × 5 m.

The species were hand broadcast into well cultivated seed beds at UBU on May 7, and at YNS and YAC on May 13, 1998 and the seed lightly surface raked into the soil. The plots were fertilised at sowing with N (20 kg/ha), K (25 kg/ha), P (10 kg/ha) and S (10 kg/ha).

Plant counts were made in four $0.25m^2$ quadrats per plot, 6 weeks after sowing. Dry matter cuts were taken from four $0.25m^2$ quadrats at 5 cm from ground level in each plot on 3 occasions in the first wet season, twice in the first dry season, once at YNS and twice at UBU and YAC in the second wet season and once in the second dry season at UBU. No cuts were taken at YAC and YNS in the second dry season.

At each sampling, total fresh weight was recorded and a 200 g subsample was dried as in Trial 1. After each sampling, all plots were topped as described for Trial 1 and fertilised with K (25 kg/ha), P (10 kg/ha) and S (10 kg/ha).

Data from all trials were analysed using the IRRISTAT programme for conventional analyses of randomised block experiments.

Results

Soil

Soils at all sites were acid, with pH ranging from 4.6 at UAC to 5.6 at YAC (Table 1). The soils were low in N (0.02–0.07%), P (2–11 ppm; Bray II extraction method) and organic matter (0.2–1.4%). All soils contained more than 60% sand except for the soil at UAC which was 67% silt.

Rainfall

Average rainfall for all trial sites from 1997–1999 was similar, ranging between 1300–1600 mm,

Table 1. Soil analysis of trial sites.

Site[1]	pH (1:5 water)	Total N	P	OM	Sand	Silt
		(%)	(ppm)	(%)	(%)	(%)
UBU Trial 1	5.3	0.02	7.9	1.0	66	34
UBU Trials 2 & 3	5.3	0.02	9.5	1.1	64	35
MUK	5.2	0.02	5.0	1.2	69	30
DET	4.9	0.02	2.3	1.4	61	39
YNS	5.4	0.02	4.9	1.3	85	14
YAC	5.6	0.04	7.4	0.6	62	37
SAC	5.2	0.03	11.7	1.1	64	35
UAC	4.6	0.07	4.2	0.2	31	67

[1]UBU = Ubon Ratchathani University Farm; MUK = Mukdahan Animal Nutrition Station; DET = Village in Det Udom district of Ubon Ratchathani Province; YNS = Yasothon Animal Nutrition Station; YAC = Yasothon Agricultural Technology College Farm; SAC = Sisaket Agricultural Technology College Farm; UAC = Ubon Ratchathani Agricultural Technology College Farm.

and most sites experienced good wet season rainfall (Table 2). The site at YNS was the only site to have an early season moisture deficit in 1997 and 1998.

Trial 1 — Evaluation of grasses sown with legumes

Grasses. Plant density of most grass species was good at 6 weeks after sowing (Table 3), except for signal at all sites and Purple guinea at MUK. Plant densities at DET were 2–3 times higher overall than those at UBU and MUK.

Plicatulum produced the most dry matter (13 t/ha) at all sites in the first wet season (Table 4) followed by Ubon paspalum at UBU and DET and Purple guinea and ruzi at MUK. Purple guinea produced significantly less dry matter than plicatulum and Ubon paspalum at UBU and DET. At all sites, yields of signal and Jarra digit were less than half that of plicatulum in the first wet season.

In the first dry season, signal produced high dry matter yields at UBU and MUK but not at DET, and first dry season production of Ubon paspalum was also high at all sites (Table 4).

In the second wet season, Purple guinea produced in excess of 33 t/ha DM at MUK followed by Ubon paspalum, Jarra digit and plicatulum which produced more than 20 t/ha DM (Table 4). At UBU, Purple guinea, Splenda setaria, ruzi, Ubon paspalum and signal also produced more than 20 t/ha DM in the second wet season. Ruzi and Jarra digit died out at the DET site in the second wet season and signal and Purple guinea produced very low yields.

In the second dry season at UBU, there were no significant differences in dry matter production between species but, at MUK and DET, Purple guinea and plicatulum, respectively, were the most productive grasses (Table 4).

Ubon paspalum, plicatulum, Purple guinea and Jarra digit produced the highest dry matter yields at both UBU and MUK in the third wet season (Table 4). Ubon paspalum, Splenda setaria and plicatulum produced the highest yields at DET in both the third wet and dry seasons. In the third dry season at MUK, Purple guinea produced over 12 t/ha DM, which was nearly 40% more than the second most productive grasses, Ubon paspalum and signal (Table 4).

Legumes. Plant density of all legumes 6 weeks after sowing was considerably less than that of the grasses except at MUK, where total legume numbers were generally greater than grass numbers (Table 3). Verano stylo and Cavalcade plant numbers were sparse at all sites.

In the first wet season, legumes at MUK produced 4–5 times more dry matter than legumes at UBU and DET (Table 4). Calopo was the main legume at MUK, growing from buried seed from the previous pasture (data for individual legumes not presented). Llanos macro also grew well in the first wet season at MUK and UBU. Lee jointvetch was the best producing legume at DET in the first wet season. However, by the third cut in October 1997, legumes at all sites were very sparse.

Legumes in all plots died out during the first dry season but grew again from fallen seed as a minor component in the swards in the early part of the second wet season (Table 4). The main leg-

Table 2. Rainfall for the trial sites.

Month	Rainfall (mm)																	
	UBU[1]			UAC			YNS			MUK			DET			SAC		
	1997	1998	1999	1997	1998	1999	1997	1998	1999	1997	1998	1999	1997	1998	1999	1997	1998	1999
Jan	3	0	1	0	0	0	0	0	0	0	0	6	2	1	0	0	0	0
Feb	2	44	3	7	58	23	47	25	0	32	35	0	22	115	0	26	68	0
Mar	71	0	92	41	0	96	41	0	32	46	15	18	27	7	107	36	0	103
Apr	52	60	92	82	75	125	99	37	97	64	24	103	151	116	159	101	33	115
May	150	294	235	194	244	305	47	197	251	115	217	345	153	279	222	284	224	138
Jun	352	183	221	312	154	251	314	75	190	283	335	121	173	52	245	167	101	126
Jul	399	168	291	453	155	279	432	160	228	120	81	368	449	173	265	340	229	245
Aug	324	193	96	224	241	129	337	292	157	407	215	157	265	274	98	156	286	129
Sep	239	208	256	157	201	166	118	163	293	172	223	263	239	190	245	267	289	201
Oct	107	85	95	86	69	201	57	67	111	180	28	30	122	116	98	170	118	99
Nov	0	106	0	0	117	6	0	67	9	0	9	11	0	78	21	0	98	16
Dec	0	0	0	0	3	1	0	0	0	0	4	0	0	1	0	0	2	0
Total	1554	1341	1382	1556	1317	1582	1492	1083	1368	1423	1186	1422	1601	1402	1460	1547	1448	1172

[1]UBU = Ubon Ratchathani University Farm; UAC = Ubon Ratchathani Agricultural Technology College Farm; YNS = Yasothon Animal Nutrition Station; MUK = Mukdahan Animal Nutrition Station; DET = Village in Det Udom district of Ubon Ratchathani Province; SAC = Sisaket Agricultural Technology College Farm.

Table 3. Plant populations (6 weeks after sowing) in grass-legume swards at UBU, MUK and DET (Trial 1).

Treatment	Grass	Lee jointvetch	Verano stylo	Cavalcade	Llanos macro	Total legume
			(plant/m^2)			
			UBU[1]			
Ruzi	52cde[2]	11abc	3a	7a	22ab	43ab
Signal	22e	7bc	2a	7a	4c	20b
Jarra digit	69bcd	13abc	3a	8a	9abc	33ab
Ubon paspalum	109a	14ab	3a	11a	22ab	50a
Plicatulum	98ab	9bc	2a	11a	24a	46a
Purple guinea	42de	21a	4a	8a	18abc	51a
Splenda setaria	89abc	3c	3a	7a	6bc	19b
			MUK[1]			
Ruzi	59cd	60a	10ab	8a	32b	110a
Signal	17d	68a	11ab	9a	39ab	127a
Jarra digit	41cd	52a	8ab	8a	30b	98a
Ubon paspalum	140b	41a	10ab	5a	32b	88a
Plicatulum	245a	50a	11a	4a	54a	119a
Purple guinea	6d	48a	5ab	7a	33b	93a
Splenda setaria	111bc	66a	4b	9a	41ab	120a
			DET[1]			
Ruzi	112de	53a	9a	11a	18a	91a
Signal	28e	64a	7a	9a	21a	101a
Jarra digit	219cd	67a	9a	11a	19a	106a
Ubon paspalum	346bc	72a	10a	9a	17a	108a
Plicatulum	587a	66a	6a	11a	19a	102a
Purple guinea	169de	60a	7a	9a	17a	93a
Splenda setaria	455ab	63a	7a	9a	19a	98a

[1]UBU = Ubon Ratchathani University Farm; MUK = Mukdahan Animal Nutrition Station; DET = Village in Det Udom district of Ubon Ratchathani Province.
[2]Within columns and sites means followed by a common letter are not significantly different at P=0.05 by Duncan's Multiple Range Test.

umes were Llanos macro, Calopo and Lee jointvetch at UBU, MUK and DET, respectively. Following the first cut in the second wet season, legumes died out at all sites and failed to reappear for the duration of the trial.

Trial 2 — Evaluation of grasses sown with Tha Phra stylo

Plant populations of Ubon paspalum, plicatulum and Splenda setaria at 6 weeks after sowing exceeded 200 plants/m^2 at UBU, YNS and UAC and 100 plants/m^2 at YAC and SAC (Table 5). Density of signal, Jarra digit and Purple guinea was lower at 19–85 plants/m^2. The average densities of Tha Phra stylo at UBU and UAC (135 and 173 plants/m^2) were higher than those at the other sites (71 plants/m^2).

In the first wet season, Ubon paspalum and plicatulum tended to produce the most dry matter at all sites (Table 6). However, there were few significant differences in dry matter production between most species. Signal and Jarra digit were the least productive species at all sites. Dry matter production at SAC was affected by severe waterlogging from August–October. Tha Phra stylo was generally sparse in the productive grass swards in the first wet season at UBU, YNS and YAC, contributing less than 5% of total dry matter (Table 6). At SAC and UAC, where grass production was lower than at the other sites, Tha Phra stylo represented a higher percentage of total dry matter.

In the first dry season, Ubon paspalum and plicatulum produced high dry matter yields at all sites (Table 7) followed by signal, Purple guinea and Splenda setaria. Jarra digit was the least productive species at all sites. In most plots, Tha Phra stylo contributed about 5% of total

Table 4. Dry matter production from grass-legume swards at UBU, MUK and DET (Trial 1).

Treatment (Year)	Wet (97)			Dry (97–98)	Wet (98)			Dry (99)	Wet (99–00)	Dry (00)
	G[2]	L	T	G	G	L	T	G	G	G
					(t/ha) UBU[1]					
Ruzi	9.4b[3]	0.3bc	9.7bc	2.5d	22.6a	0.3c	22.9a	5.4a	9.5c	6.8a
Signal	5.5c	2.2a	7.7cd	6.1a	20.3ab	0.7c	21.1ab	6.5a	9.6c	7.8a
Jarra digit	6.1c	0.1c	6.2d	1.6d	16.7bc	1.8b	17.8bc	5.9a	10.3bc	5.9a
Ubon paspalum	10.2b	1.4ab	11.6ab	5.8ab	20.9a	0.2c	21.1ab	5.3a	12.9a	6.7a
Plicatulum	13.4a	0.7bc	14.1a	5.2abc	16.2c	0.1c	16.3c	5.2a	12.4ab	6.7a
Purple guinea	5.1c	0.6bc	5.7d	3.5cd	23.6a	0.4c	24.0a	5.9a	10.6abc	7.5a
Splenda setaria	7.5bc	0.7bc	8.2cd	3.6bcd	22.7a	2.4a	25.1a	6.8a	9.9c	7.9a
					MUK[1]					
Ruzi	12.4a	3.2b	15.7ab	4.9bc	19.1c	1.0b	20.1c	2.2de	12.2b	5.8c
Signal	6.0b	5.8ab	11.8bc	7.7a	18.7c	0.8bc	19.5c	3.2bc	11.4b	7.1b
Jarra digit	5.4b	4.8ab	10.2c	5.0bc	22.3bc	0.5c	22.9bc	2.7cd	16.0ab	6.3bc
Ubon paspalum	9.9ab	6.2a	16.1ab	7.0ab	26.3b	0.1c	26.4b	3.4b	17.5a	7.0b
Plicatulum	13.6a	4.5ab	18.1a	4.5c	20.3c	0.1c	20.4c	2.3de	15.1ab	4.7c
Purple guinea	11.6a	6.8a	17.9a	7.6a	33.9a	1.1b	35.0a	4.2a	19.2a	12.4a
Splenda setaria	8.6ab	5.1ab	13.7abc	3.5c	17.5c	2.1a	19.6c	1.7e	12.2b	4.7c
					DET[1]					
Ruzi	5.6c	0.06b	5.66c	0.02b	—[4]	—	—	—	—	—
Signal	3.3c	1.7a	5.0c	0.7b	4.9b	0.4a	5.3b	6.8b	3.2bc	0.4c
Jarra digit	4.8c	0.05b	4.85c	0.04b	—	—	—	—	—	—
Ubon paspalum	10.5ab	0.5b	11.0a	4.4a	14.6a	0.3a	14.9a	5.6b	10.2a	5.0a
Plicatulum	13.0a	0.06b	13.06a	5.5a	13.9a	0.3a	14.2a	10.0a	6.1ab	3.6b
Purple guinea	5.7c	1.3ab	7.0bc	1.1b	2.5b	0.5a	3.0b	1.0c	1.3bc	—
Splenda setaria	9.6b	0.1b	9.7ab	4.5a	13.3a	0	13.3a	6.6b	9.6a	6.8a

[1]UBU = Ubon Ratchathani University Farm; MUK = Mukdahan Animal Nutrition Station; DET = Village in Det Udom district of Ubon Ratchathani Province.
[2]G = Grass; L = Legume; T = Total (G + L).
[3]Within columns and sites, means followed by a common letter are not significantly different at P=0.05 by Duncan's Multiple Range Test.
[4]Species not present.

sward dry matter yields in the first dry season but in some plots it died out (Table 7).

In the second wet season, all grass species produced well at UBU, with mean yield exceeding 16 t/ha DM (Table 8). Ubon paspalum, plicatulum and Purple guinea produced equally high yields at YNS and YAC. At UAC, Purple guinea produced nearly 7 t/ha DM more than Ubon paspalum and plicatulum but at SAC, yield of Purple guinea was only half that of these 2 species. Tha Phra stylo died out in all plots at YAC and was present in plots at other sites only at the first sampling cut (Table 8). By the second dry season, it was no longer present in any plots at all sites.

The trials at SAC, YAC and UAC were terminated early in the second dry season following uncontrolled grazing or cutting. In the second dry season at UBU and YNS, Purple guinea produced higher dry matter yields than other species but these differences were significant only at UBU (Table 9).

Trial 3 — Evaluation of legumes

All legume species had achieved good plant densities at all sites at 6 weeks after sowing (Table 10). Plant numbers of Llanos macro, Tha Phra stylo and Lee jointvetch were high at UBU.

In the first wet season, Lee American jointvetch at YAC produced 14 t/ha, nearly 3 times more than the second best legume, Llanos macro (Table 11). Llanos macro produced nearly twice the amount of dry matter of other legumes at UBU except for Lee jointvetch.

Table 5. Plant populations (6 weeks after sowing) of grass species and Tha Phra stylo at UBU, YNS, YAC, SAC and UAC (Trial 2).

Treatment	UBU[1]	YNS	YAC	SAC	UAC
			(plants/m^2) Grass		
Ruzi	85c[2]	95b	70bcd	61c	118b
Signal	43c	50b	20d	19c	46bc
Jarra digit	52c	47b	31d	25c	30c
Ubon paspalum	225b	228a	149ab	156a	232a
Plicatulum	351a	200a	188a	176a	270a
Purple guinea	85c	59b	45cd	54c	48bc
Splenda setaria	287ab	217a	122abc	111b	266a
			Tha Phra stylo		
Ruzi	102a	69abc	50ab	67a	163ab
Signal	135a	113a	46ab	112a	237a
Jarra digit	150a	112ab	32b	78a	200ab
Ubon paspalum	144a	63bc	64ab	76a	131b
Plicatulum	168a	49c	39b	69a	122b
Purple guinea	125a	82abc	77a	63a	190ab
Splenda setaria	118a	99abc	43ab	92a	170ab

[1]UBU = Ubon Ratchathani University Farm; YNS = Yasothon Animal Nutrition Station; YAC = Yasothon Agricultural Technology Farm; SAC = Sisaket Agricultural Technology College Farm; UAC = Ubon Ratchathani Agricultural Technology College Farm.
[2]Within columns and plant type, means followed by a common letter are not significantly different at P=0.05 by Duncan's Multiple Range Test.

Table 6. Dry matter production of grass species and Tha Phra stylo in the first wet season after planting at UBU, YNS, YAC, SAC and UAC (Trial 2).

Treatment	UBU[1]	YNS	YAC	SAC	UAC
			(t/ha) Grass		
Ruzi	12.4ab[2]	8.8abc	13.7a	3.4ab	6.8b
Signal	6.5bc	4.6cd	6.9b	0.6d	2.3cd
Jarra digit	4.6c	1.2d	4.2b	1.7cd	0.9d
Ubon paspalum	14.1a	9.8a	16.6a	4.4a	10.3a
Plicatulum	14.9a	9.2ab	13.4a	4.3a	9.7a
Purple guinea	13.5a	7.4abc	14.4a	2.1bc	5.0bc
Splenda setaria	9.3abc	5.0bcd	13.7a	2.2bc	6.3b
			Tha Phra stylo		
Ruzi	0.87b	0.21b	0.06ab	0.38bc	0.05c
Signal	2.08a	0.68a	0.14ab	0.72a	1.44a
Jarra digit	1.81a	0.73a	0.05ab	0.17c	1.09ab
Ubon paspalum	0.79b	0.11b	0.09ab	0.34bc	0.34c
Plicatulum	0.63b	0.25b	0.03b	0.24c	0.29c
Purple guinea	1.94a	0.71a	0.24a	0.61ab	0.94b
Splenda setaria	1.15ab	0.32b	0.06ab	0.45abc	0.48c

1UBU = Ubon Ratchathani University Farm; YNS = Yasothon Animal Nutrition Station; YAC = Yasothon Agricultural Technology Farm; SAC = Sisaket Agricultural Technology College Farm; UAC = Ubon Ratchathani Agricultural Technology College Farm.
[2]Within columns and plant type, means followed by a common letter are not significantly different at P=0.05 by Duncan's Multiple Range Test.

Table 7. Dry matter production of grass species and Tha Phra stylo in the first dry season after planting at UBU, YNS, YAC, SAC and UAC (Trial 2).

Treatment	UBU[1]	YNS	YAC	SAC	UAC
			(t/ha) Grass		
Ruzi	3.2bc[2]	4.6ab	3.2b	0.6b	2.6d
Signal	5.0ab	4.4ab	4.7a	0.2b	3.5bc
Jarra digit	2.9c	2.6b	0.8c	0.1b	1.0e
Ubon paspalum	4.5abc	4.4ab	5.0a	6.6a	4.9a
Plicatulum	4.8ab	3.7ab	5.0a	8.2a	3.8b
Purple guinea	5.5a	5.6ab	2.9b	0.7b	4.0b
Splenda setaria	3.4bc	6.7a	2.5b	6.2a	2.8cd
			Tha Phra stylo		
Ruzi	0.86a	0.20a	—[3]	1.23a	0.27a
Signal	0.98a	0.30a	0.03a	0.86a	0.23a
Jarra digit	1.01a	0.31a	0.09a	1.01a	0.30a
Ubon paspalum	0.20a	—	0.04a	0.97a	—
Plicatulum	0.20a	0.03a	0.03a	1.14a	—
Purple guinea	0.20a	0.53a	0.09a	0.47a	0.08a
Splenda setaria	0.31a	0.52a	0.06a	0.20a	0.12a

[1]UBU = Ubon Ratchathani University Farm; YNS = Yasothon Animal Nutrition Station; YAC = Yasothon Agricultural Technology Farm; SAC = Sisaket Agricultural Technology College Farm; UAC = Ubon Ratchathani Agricultural Technology College Farm.
[2]Within columns and plant type, means followed by a common letter are not significantly different at P=0.05 by Duncan's Multiple Range Test.
[3]Species not present.

Table 8. Dry matter production of grass species and Tha Phra stylo in the second wet season after planting at UBU, YNS, YAC, SAC and UAC (Trial 2).

Treatment	UBU[1]	YNS	YAC	SAC	UAC
			(t/ha) Grass		
Ruzi	14.4a[2]	14.9ab	16.7cd	0.6d	20.1b
Signal	13.6a	12.3b	12.5d	2.4cd	18.5b
Jarra digit	14.7a	3.4c	12.7d	4.8c	19.4b
Ubon paspalum	16.4a	17.4a	22.5a	17.1a	22.6b
Plicatulum	17.9a	16.2a	20.3abc	15.9a	23.9b
Purple guinea	18.2a	17.3a	21.7ab	8.1b	31.1a
Splenda setaria	18.6a	11.9b	17.3bcd	13.9a	20.4b
	Tha Phra stylo				
Ruzi	0.47ab	0.12a	—[3]	0.89ab	0.14a
Signal	0.29ab	—	—	1.15a	0.30a
Jarra digit	0.57a	0.12a	—	0.53ab	0.16a
Ubon paspalum	0.06b	—	—	0.12b	0.21a
Plicatulum	0.09ab	—	—	0.04b	—
Purple guinea	—	0.12a	—	0.55ab	0.27a
Splenda setaria	—	0.31a	—	0.09b	0.33a

[1]UBU = Ubon Ratchathani University Farm; YNS = Yasothon Animal Nutrition Station; YAC = Yasothon Agricultural Technology Farm; SAC = Sisaket Agricultural Technology College Farm; UAC = Ubon Ratchathani Agricultural Technology College Farm.
[2]Within columns and plant type, means followed by a common letter are not significantly different at P=0.05 by Duncan's Multiple Range Test.
[3]Species not present.

Table 9. Dry matter production of grass species in the second dry season after planting at UBU and YNS (Trial 2).

Treatment	UBU[1]	YNS
	(t/ha)	
Ruzi	10.3b[2]	5.2b
Signal	11.9ab	8.8a
Jarra digit	8.6b	1.7c
Ubon paspalum	9.8b	7.2a
Plicatulum	10.4b	8.6a
Purple guinea	14.5a	9.3a
Splenda setaria	10.9b	7.8a

[1]UBU = Ubon Ratchathani University Farm; YNS = Yasothon Animal Nutrition Station.
[2]Within columns, means followed by a common letter are not significantly different at P=0.05 by Duncan's Multiple Range Test.

Table 10. Plant populations (6 weeks after sowing) of legume species at UBU, YNS and YAC (Trial 3).

Treatment	UBU[1]	YNS	YAC
		(plants/m^2)	
Verano stylo	86c[2]	97a	46c
Tha Phra stylo	173b	119a	108b
Cavalcade centurion	40d	51a	29c
Calopo	36d	60a	22c
Llanos macro	171b	86a	178a
Puero	60cd	56a	14c
Lee jointvetch	221a	53a	89b

[1]UBU = Ubon Ratchathani University Farm; YNS = Yasothon Animal Nutrition Station; YAC = Yasothon Agricultural Technology Farm.
[2]Within columns, means followed by a common letter are not significantly different at P=0.05 by Duncan's Multiple Range Test.

Table 11. Dry matter production of legume species at UBU, YNS and YAC (Trial 3).

Treatment	First wet season			First dry season		Second wet season		
	UBU[1]	YNS	YAC	UBU	YNS	UBU	YNS	YAC
				(t/ha)				
Verano stylo	3.7b[2]	3.0a	3.9bc	1.3b	1.1ab	6.1a	0.6a	5.2a
Tha Phra stylo	3.4b	3.5a	3.9bc	3.7a	1.6a	7.1a	0.9a	2.5bc
Cavalcade	4.6b	1.8ab	4.0bc	0.4b	0.3b	0.8b	—[3]	0.6cd
Calopo	4.4b	2.2ab	3.3bc	0.3b	0.1b	0.6b	0.2b	0.2d
Llanos macro	8.0a	3.3a	5.5b	4.6a	2.1a	1.9b	0.1b	3.2b
Puero	3.2b	0.2b	1.4c	0.2b	—	0.2b	—	1.0cd
Lee jointvetch	5.3ab	2.5a	14.0a	1.7b	—	2.3b	0.1b	0.7cd

[1]UBU = Ubon Ratchathani University Farm; YNS = Yasothon Animal Nutrition Station; YAC = Yasothon Agricultural Technology Farm.
[2]Within columns, means followed by a common letter are not significantly different at P=0.05 by Duncan's Multiple Range Test.
[3]Species not present

In the first dry season, Llanos macro and Tha Phra stylo were the best performing legumes at UBU and YNS, followed by Verano stylo (Table 11). At YAC, no dry season data were collected as all legume plots were heavily smothered with *Mimosa pudica.*

However, all legumes at YAC re-established from fallen seed in the second wet season. These new plants plus surviving plants grew well and Verano stylo produced more than 5 t/ha DM (Table 11). At UBU, Verano stylo and Tha Phra stylo were very productive, producing 6 and

7 t/ha DM, respectively. Legumes at YNS were sparse and only 1 cut was taken at the end of the wet season.

In the second dry season, the trial at YAC was grazed and at YNS no legumes grew at all with two main weed species, *Melochia corchorifolia* and *Corchorus olitorius,* smothering the plots. At UBU, only Tha Phra stylo and Verano stylo grew, producing 4 and 0.6 t/ha, respectively. In the remaining plots, *Eremochloa ciliaris* grew vigorously.

Discussion

This study found that none of the legumes tested was able to persist either in pure swards or when growing with N-fertilised grass under cutting on low lying sites in north-east Thailand, confirming the results found earlier by Hare *et al.* (1999a). Establishment of legumes has never been a problem on such sites, with many legumes in pure swards producing over 4 t/ha DM in the first growing season and even reaching 14 t/ha DM, as was the case with Lee American jointvetch at one site (Table 11). The difficulty of legume persistence thereafter appears to be a combination of wet and dry conditions, competition from N fertilised grasses and cutting management.

We may have more success with legumes if we cut less frequently at a greater height, 20–30 cm above ground level, rather than cutting every 45–55 days to 5 cm above ground level. However, this would necessitate a change of management by village farmers who raise livestock.

Our philosophy in introducing legumes and grasses to village farmers is that the selected plants must be adapted to the current low cutting or continuous grazing management currently practised by livestock farmers. This is why Verano stylo has been so successful in upland, well drained soils in north-east Thailand. It tolerates heavy grazing and being a prolific seeder, even under these conditions, re-establishes itself each year (Hare and Phaikaew 1999). If we were to recommend less frequent and high cutting to livestock farmers, this would introduce an additional management factor for farmers to consider. Just getting farmers to establish improved species and apply fertiliser is an achievement in itself. Getting them to adopt a different cutting management for legumes will take time.

In these studies, nitrogen was applied frequently in order to study the potential of the grasses to produce on these very difficult infertile soils. Previous studies had found that, with either no nitrogen or less frequent applications, grasses quickly became very yellow and nitrogen-deficient (Hare *et al.* 1999c). Applications of more than 100 kg/ha N are far in excess of what smallholder farmers would apply to their pastures. Normal rates in villages would be either no fertiliser or 1 application of 20 kg/ha N in the wet season. Thus, pastures commonly die out within 2 years from a combination of lack of fertiliser and close and frequent grazing or cutting.

At the beginning of the study, we considered that *S. guianensis* CIAT 184 (Tha Phra stylo) would be successful. To a limited extent it was as, in pure swards, it persisted into the second wet season but only in a few plots into the second dry season. The cutting management we used may be a factor in its lack of persistence. *S. guianensis* CIAT 184 grew well in the American tropical rainforest ecosystem after one cut at 12 weeks of age (Amezquita *et al.* 1991). In China, it is usually cut only once a year when grown for feed meal production or as a cover crop (Guodao and Kerridge 1997). Where more frequent cutting has been practised in China, the sites have been on well drained, high pH (6.4), reddish brown, lateritic soils (Guodao and Kerridge 1997) and not on poorly drained, infertile, low pH, sandy soils like those used in the current study in Thailand. However, on well drained, upland soils in north-east Thailand, CIAT 184 grows very well, and in current trials at UBU, CIAT 184 and the hybrid stylo (ATF 3308 *S. guianensis* var. *vulgaris* × var. *pauciflora)*, produced 9030 and 8470 kg/ha DM, respectively, in the first wet season and 4024 and 2639 kg/ha DM in the first dry season. The cutting was infrequent with only 2 wet season cuts and 1 dry season cut. In our own pasture programme at UBU, pure stands of Tha Phra stylo and the hybrid stylo (ATF 3308) are grazed to about 30 cm height and closed to grazing during the main flowering and seed-set period from December–February.

We expected to have more success with Lee American jointvetch given that an annual ecotype of *Aeschynome americana* grows naturally in wet areas along roadsides and around swampy ungrazed wasteland in north-east Thailand. This native legume is rarely cut for forage and is allowed to grow rank and set seed every year. Cutting once a year at the end of the dry season enabled Glenn American jointvetch to grow well for 3 years on seasonally flooded clay and solodic soils in the Northern Territory, Australia (Ross and Cameron 1991). It was able to re-establish each year from fallen seed. This current study showed that Lee has the potential to grow well here, as it produced 14 t/ha DM at one site in the first growing season. Studies of persistence mechanisms could result in management strategies that would improve persistence of Lee under cutting.

However, cropping farmers do have more success with legumes if they regard them as annual cash crops to sell to livestock farmers as fresh grass or hay and cut only once or twice a year. On well drained upland soils, several legumes are being promoted as cash crops by the Department of Livestock Development in Thailand for specialist fresh forage and hay production (Khemsawat and Phonbumrung 2002). The main legume is Cavalcade and more than 3000 farmers will grow up to 0.32 ha for sale to other farmers. They will not use the forage for themselves. The other legumes are Verano stylo and Tha Phra stylo. Under once or twice-a-year cutting all of these legumes grow very well but they have to be replanted each year as the last cut is before seed set.

This study found that, on sites deeply waterlogged in the wet season (DET and SAC), only 3 grass species (Ubon paspalum, plicatulum and Splenda setaria) were able to persist, confirming the earlier results of Hare *et al.* (1999a).

On sites that were wet but not severely waterlogged, Purple guinea grass was either equal in production to or more productive than these 3 species. Purple guinea is a good quality pasture grass and, on sites such as MUK, has the potential to produce in excess of 33 t/ha DM in a 6-month wet season. Even in the second and third dry seasons on these low lying sites, no species produced more dry matter during the dry season than Purple guinea grass. We therefore recommend Purple guinea grass as a "cut-and-carry" forage for non-waterlogged sites in Thailand. It is currently one of the best grass species recommended for planting in backyard forage plots and for hay and silage production by the Department of Livestock Development in Thailand (Khemsawat and Phonbumrung 2002).

Ruzi, signal grass and Jarra digit performed best on sites that did not become inundated with water in the wet season. However, even on these sites, they were not as productive as Ubon paspalum, plicatulum and Purple guinea grass. On the inundated sites, they either produced low yields or died out.

Rainfall during the studies (1997–1999) was average at all sites. However, rainfall in the 2000 wet season was 30–50% above average at most sites. Unfortunately, the trial areas had either been grazed or cultivated so no data could be collected from the grass species growing under wetter-than-normal field conditions. Observations from our university pastures showed that, under these very wet-waterlogged conditions, Ubon paspalum, plicatulum and Splenda setaria performed the best. Signal grass, ruzi, Jarra digit and Purple guinea struggled to survive in places that were inundated with water for periods longer than 1 month.

Acknowledgements

We thank the Thailand Research Fund (TRF) for providing financial support for this research program; the Faculty of Agriculture, Ubon Ratchathani University for research facilities; and the Department of Livestock Development and the Agricultural Colleges for research sites and assistance on their field stations. We also thank Mr Kittipat Saipraset for technical assistance.

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(Received for publication January 4, 2002; accepted October 31, 2002)