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The Effects of Intercropping with Four Tropical Legume Species on the Yield and Quality of Napier Grass in Thailand

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ABSTRACT

A comparison of yield and quality of napier Taiwan A25 (*Pennisetum purpureum*) intercropped with four different legume species (*Cajanus cajan*, *Crotalaria juncea*, *Leucaena leucocephala* and *Sesbania luteola*) was carried out at the National Corn and Sorghum Reseaech Center, Pakchong district, Nakornratchasima, Thailand, over a 12-month period. The objective was to determine the optimal combination of legume species and the proportion of grass/legume in napier fodder banks in Thailand.

The design of the experiment was a split plot with legume species as the main plot and the ratio between rows of grass and legume (1 : 1, 1 : 2 and 1 : 4) as sub – plot.

The results showed that crotalaria produced the highest total dry matter yield followed by leucaena, pigeon pea and sesbania. Grass yield was highest in the crotalaria plots and lowest in the leucaena plots. Thus, the total dry matter yield (grass + legume) was highest in the crotalaria plots and lowest in the leucaena plots. However, sesbania and crotalaria produced substantial yields only during the first two cuts with yields declining dramatically. Increasing the ratio between grass and legume resulted in a greater legume yield. The recommendation for the ratio between grass and legume was 1 : 2 (1 row grass : 2 rows legume).

INTRODUCTION

Thailand has a very large number of livestock with the numbers in 2004 being : beef cattle 5.3 millions; buffalo 1.7 millions and dairy cows 400,000 head plus small numbers of sheep and goat (Anon, 2005). These animals are mainly raised on poor natural grassland and less than 5% of these pastures have been improved since 1990 (Tudsri and Kaewkunya, 2002). The forage yields of these natural grasslands are generally low and of poor quality due to weed invasion and the rapid maturity of tropical grass pasture which produce feed of low protein content resulting in low animal intake of digestible nutrients (Falvey *et al*., 1980). Even with cultivated tropical grass species, the quality is still relatively low when compared with the temperate grass species (Minson and McLeod, 1970, Punyavirocha *et al*., 1992 and Tudsri and Wongsuwan, 1996) and is also highly variable between genera and species (Holm, 1973). Hence, animal productivity in Thailand is poor compared with that of temperate regions (Whiteman, 1980)

The need for high quality feed for

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livestock in Thailand has lead some researchers to consider the possibility of introducing an intercropping system of grass and legume to increase the production of high quality forage. For example, Tudsri *et al*. (2001, 2002) studied the intercropping of leucaena in napier and ruzi grass and Sampet (1991) also intercropped leucaena in guinea grass. These authors had found that the presence of leucaena in pastures significantly increased the level of crude protein in the mixed forage (grass + legume) ration and hence the potential value of the feed to livestock. In Kenya, Nyaata *et al*. (1998) also reported a significant increase in annual dry matter yield over that from a pure stand of napier grass when luecaena was intercropped with the grass.

In terms of the establishment and cutting management Nyaata *et al*. (1998) and Tudsri *et al*. (2002) suggested growing grass and leucaena in alternate rows (1 : 1) or two rows of leucaena to one row of napier (2 : 1). For cutting management, Tudsri *et al*. (2002) also suggested that the cutting interval for intercropping leucaena and ruzi or Taiwan A25 was 40 days but more frequently at 30 days intervals for dwarf napier. However, Cobbina (1998) observed that the leucaena tree when cut less frequently developed a bigger stump and thus, it was necessary to find other more suitable legume species to replace leucaena as a companion to the associated grass species. Of these legumes, pigeon pea (*Cajanus cajan*), sesbania (*Sesbania luteola*) and crotalaria (*Crotalaria juncea*) were considered to be among the most promising on the basis of their ease of propagation, vigor of growth and forage dry matter production (Thanomwongwathana, 1994). However, the production and changes in quality when intercropping these legumes with napier grass have not been studied in Thailand. Phaikaew *et al*. (1998) studied the intercropping of pigeon pea in ruzi grass and found that pigeon pea could produce good yields even in the dry season. The maximum growth rate of pure stand of pigeon pea was recorded between 10 – 12 weeks after sowing (Tanomwongwathana, 1994).

Taiwan A25 is an accession of napier grass which was introduced to Thailand from Japan in 1993. A preliminary study revealed that it had high potential productivity when compared to ruzi grass (Tudsri *et al*., 1999). In later work at Pakchong, Tudsri *et al*. (2002) showed that it could produce yields similar to dwarf napier but the crude protein content rapidly declined with plant maturity (Riddach, 1997). Thus, the inclusion of the legumes may lead to sustainable production of high quality forage. However, suitable legumes for intercropping with Taiwan A25 have not been identified.

This study was conducted to examine the effect of intercropping with leucaena, pigeon pea, sesbania and crotalaria on the yield and quality of napier grass. The objective was to determine the optimal combination of legume species and the proportion of grass/legume in napier fodder banks in Thailand.

MATERIALS AND METHODS

The experiment was conducted on a sandy clay loam soil at the Suwanvajokkasikit Research Station, Pakchong, approximately 150 km northeast of Bangkok (long 101° 19E, lat 1438′ N, altitude 388 a.s.l.). Soil of the experimental area was classified as a moderate reddish brown laterite with a pH 6.95. The chemical content of the soil in the top 0 – 15 cm was 65 ppm available P (Bray II), 115 ppm K and 2.33% organic matter.

The design of the experiment was a split plot with three replications. The sub – plot size was 3 × 5 m. The main plots consisted of four tropical legumes : leucaena (Leu), Pigeon pea (Pig), Sesbania (Ses) and Crotalaria (Cro) planted with napier grass (Taiwan A25). The sup-plot treatments were the ratio between grass and legume viz 1 : 1 (one row of grass : one row of legume), 1 : 2 (one row of grass : two rows of

legume) and 1 : 4 (one row of grass : four rows of legume).

The area was ploughed and cultivated before sowing on March 2, 2001. Leucaena, pigeon pea, sesbania and crotalaria were scarified and planted by seed with the spacing of 50 × 50 cm apart between and within rows. All legume species were inoculated with an appropriated Rhizobium before sowing. The grass, Taiwan A25, was planted in small pots prior to transplanting into the experimental area when it had 2 – 3 leaves. An initial fertilizer dressing of 15-15-15 (N : P: K) at 300 kg/ha was applied at sowing. The area was cut by hand to 10 cm for grass and 50 cm for legumes on July 15, 2001. This date was taken at day 0, and the cutting intervals of 30 days commenced from that date (except in the last cutting in March 2002 which was carried out 90 days after the previous cut).

Grass dry matter yields were measured in an area of 7.5 m^2 by cutting with hand shears to 10 cm in each plot. Leucaena was also cut at 50 cm to measure the dry matter yield. A 300 g subsample was separated into leaf and stem components dried at 80°C for 72 h and dry weight recorded. The dry leaf and stem samples were analyzed for N to calculate crude protein contents (% N × 6.25), and also for % P(O'Neill and Webb, 1970) by using Technical Autoanalyser. Acid detergent fiber (ADF) contents were determined according to Van Soest system (Van Soest, 1967) for both grass and legumes.

RESULTS

Rainfall

Monthly recording of rainfall, mean temperatures of average 30°C maximum and 25° C minimum and of an average 72% relative humidity over the period of the experiment (March 2001 – March 2002) is shown in Table 1. Soil moisture conditions at sowing on March, 2001 were good. Good rainfall was recorded from March 2001 until May 2001 after which the amount of rainfall declined during June and July. However, a substantial amount of rainfall was recorded in August, September and October before the start of a dry cool period from November 2001

Table 1 Total monthly rainfall, relative humidity and maximum and minimum temperature at Suwanvajokasikit Research Station.

Month	Rainfall	Temperature (°C)		Relative humidity
	(mm)	Maximum	Minimum	%
Mar 2001	91.3	30.9	21.6	76
Apr	115.1	34.4	23.2	72
May	281.6	31.2	23.2	78
Jun	74.0	31.0	23.3	75
Jul	70.2	31.0	23.9	72
Aug	108.4	30.0	23.6	75
Sep	160.4	31.1	22.4	80
Oct	144.2	30.5	22.1	83
Nov	6.5	28.1	18.1	68
Dec	0	29.3	18.6	63
Jan 2002	0.7	30.1	17.6	61
Feb	11.1	32.5	20.0	62
Mar	70.7	32.6	21.3	71

to February 2002. During the dry conditions from November to February, the experiment was irrigated once a week and the amount of water applied was equivalent to 25 mm. of rainfall.

Grass production

The total dry matter yield of the grass over 5 harvests is presented in Table 2. Total grass yields of the crotalaria, sesbania and pigeon pea plots for the entire experimental period were similar, and were significantly higher ($P < 0.05$) than those of leucaena. This superior grass yields of the sesbania and crotalaria intercrops were only apparent at the last harvest.

Grass yields averaged across the four legume plots decreased as the grass to legume ratio increased from 1:1 to 1:4 ranging from 12,238 to 5,889 kg/ha, respectively (Table 2). There was no significant interaction between legume species and grass to legume ratios except in the first harvest only (data not presented).

Legume production

The total dry matter yield of the legumes over 5 harvests is given in Table 2. Crotalaria produced the highest yield ($P < 0.05$), while leucaena and pigeon pea were similar but less productive in total dry matter yield. All significantly out yielded sesbania. Within harvests, crotalaria and sesbania yields declined rapidly in harvests 3 – 5, while leucaena yields steadily increased during the first year of establishment.

Legume yield progressively increased as the grass to legume ratio increased form 1:1 to 1:4 ranging from 1,700 to 2,733 kg/ha,

Table 2 Effect of legume species and sowing ratio on dry matter yields of napier grass and legumes. (kg/ha).

Harvest	Coponents	A. legume species				B. Grass : Legume ratio		
		Leu.	Pig.	Seb.	Cro.	1:1	1:2	1:4
1	G[2]	1,063a[1]	1,087a	800b	969ab	1,344a	956b	638c
July-Aug.	L	338c	619bc	844ab	1,194a	600c	731b	913a
	T	1,404c	1,706b	1,644b	2,163a	1,944a	1,687b	1,551c
2	G	1,663b	2,075a	2,063a	1,850ab	2,475a	1,938b	1,325c
Aug. – Sep.	L	356c	562bc	706ab	897a	481c	631b	775a
	T	2,019b	2,637a	2,769a	2,744a	2,956a	2,569b	2,100c
3	G	1,388a	1,450a	1,475a	1,463a	1,981a	1,506b	844c
Sep. – Oct.	L	338ab	381a	238b	381a	256c	338b	413a
	T	1,726b	1,831a	1,713b	1,844a	2,237a	1,844b	1,257c
4	G	1,375a	1,388a	1,544a	1,506a	2,025a	1,450b	888c
Nov. – Dec.	L	438a	225b	44c	31c	138b	194a	219a
	T	1,813a	1,613b	1,588b	1,537b	2,163a	1,644b	1,107c
5	G	3,056b	2,988b	3,663a	3,794a	4,413a	3,519b	2,194c
Dec. – Mar.	L	838a	425b	0c	0c	225c	313b	413a
	T	3,894a	3,413b	3,663ab	3,794a	4,638a	3,832b	2,607c
Total	G	8,545b	8,988ab	9,545a	9,582a	12,238a	9,369b	5,889c
1 – 5	L	2,308b	2,212b	1,832c	2,500a	1,700c	2,207b	2,733a
	T	10,853b	11,200b	11,377ab	12,082a	13,938a	11,576b	8,622c

[1] Within row for each harvest means followed by different letter are significantly different ($P < 0.05$).

[2] G = Grass, L = Legume, T = Total (Grass + Legume).

respectively. There was no significant interaction between legume species and grass to legume ratio except in the third harvest and the total over 5 harvests.

Total production (Grass + legumes)

The highest total dry matter yields were recorded in the crotalaria/grass and sesbania/grass plots which were not significantly different whilst the first combination out yielded leucaena/grass and pigeon pea/grass plots significantly. The total dry matter yields of the latter two plots, however, did not differ significantly (Table 2).

The total dry matter yield decreased progressively as the grass : legume ratio increased. Thus, total yield reductions were greatest in the 1:4 combination (38 % of 1:1 total dry matter yield). In general, there was no significant interaction between legume species and grass to legume ratio except harvest 1 and 4.

Chemical compositions

The crude protein content of grass in the crotalaria plot was significantly higher than that in the grass grown with the other legumes, indicating a similar crude protein content (Table 3). As expected, crude protein contents of the grass leaf component was consistently higher than in the stem in all legume plots.

Crude protein of leaf in all legumes was much higher than in grass of both leaf and stem. Of the legume species, pigeon pea produced the highest crude protein content, especially, in the leaf fraction. There was no effect of grass to legume ratio on the crude protein content in both grass and legumes.

Phosphorus contents in the grass from all legume plots were similar and showed no significant differences. Of the legumes, leucaena and pigeonpea generally showed lower phosphorus content than the other legumes. In general, there was no effect of grass : legume ratio on phosphorus content. Leaf ADF contents were much lower in all legumes than in grass. Among the legume species leucaena showed the lowest ADF especially in the leaf. Grass ADF leaf was lower than in the stem, same for legume.

DISCUSSION

Results of this experiment demonstrated that legume species differed significantly in yield and their ability to sustain yield when intercropped with napier grass. Sesbania and crotalaria were annual legume with rapid growth during the early establishment (Table 2). Thus, the lower grass production in these two plots at the first harvest reflected higher competition from these legumes. Sesbania and crotalaria produced substantial yields only during the first three harvests and very little in the remaining harvests. This weak perennial legumes did not tolerate repetitive defoliation and were unable to sustain forage production under cut and carry systems.

In contrast, the perennial legumes leucaena and pigeon pea, were slow to establish but the production of dry matter yield increased over the experimental period. Nyaata *et al*. (1998) and Tudsri *et al*. (2002) reported that leucaena was productive throughout the experimental period of 3 – 4 years even in the dry season under rainfed conditions in Kenya and Thailand respectively. It seemed, therefore, that intercropping napier grass with a perennial tree legume was more advantageous than with an annual legume in the long term, although the total dry matter production (grass + legume) was lower in the establishment year. However, oversowing of annual tree legumes into the grass in the second growing season warranted further study as it was reported to be successful with herbaceous legumes such as siratro, centrosema and verano stylo (Tudsri *et al*., 1990 ; Tudsri, *et al*., 2001)

Since, pigeon pea has a similar yield to leucaena, it may, therefore, be used as an alternative perennial tree legume instead of

leucaena which has a problem with stump growth under infrequent cutting (Cobbina, 1998). Nevertheless, the present study was only carried out for one year. The long term effects in terms of yield, yield distribution and stump growth need further study. Also, pigeon pea productivity may decline after year 2 or 3 and plants die out by year 4 or 5 while leucaena yield will continue to increase until year 2 or 3 and then plateau.

These results also showed that there was a marked effect of grass to legume ratios on grass and legume yield. Increasing the ratio from 1:1 to 1:4 increased legume yield by 61 % but depressed grass yield by 108 %. As a result, total dry matter yield (grass + legume) progressively declined as the ratio increased. Nevertheless, the higher grass to legume ratio was more advantageous in terms of legume contribution to total pasture production than the lower ratio. For example, the 1:1 ratio provided average contents of 12 % legume dry matter and of 82 % grass dry matter while the 1:2 and 1:4 provided 19 and 32 % legume dry matter

Table 3 Effects of legume species and planting ratio on the chemical composition of the grass and legumes (% dry weight).

	Crude protein (%)				Phosphorus (%)				ADF (%)			
	Harvest				Harvest				Harvest			
	1		3		1		3		1		3	
	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf
1. Grass forage												
A. Legume species												
Leucaena	7.6b[1]	12.6	10.4	15.1	0.15	0.14	0.44	0.44	46.7	42.8	56.7	45.6
Pigeon pea	6.2b	11.5	9.2	14.2	0.18	0.13	0.35	0.51	54.2	41.0	58.0	39.6
Sesbania	6.6b	12.2	10.7	14.4	0.16	0.15	0.42	0.46	59.5	44.5	54.6	39.6
Crotalaria	9.1a	12.9	10.4	15.7	0.14	0.17	0.41	0.55	50.2	41.5	59.0	40.7
Mean	7.4	12.3	10.2	14.9	0.16	0.15	0.41	0.49	52.7	42.5	57.1	41.4
B. Ratio												
(Grass : legume)												
1 : 1	7.3	11.9	9.5	14.9	0.20	0.17	0.40	0.50	57.9	43.8	60.6	39.3
1 : 2	7.0	12.6	10.8	15.0	0.17	0.17	0.39	0.49	49.4	40.1	56.8	40.7
1 : 4	7.9	12.5	10.3	14.8	0.18	0.18	0.43	0.47	50.6	43.5	53.8	44.0
2. Legume forage												
A. Legume species												
Leucaena	11.2	26.5b	14.8b	25.5c	0.11b	0.22b	0.38b	0.49	65.4	25.8	62.6	36.2
Pigeon pea	12.8	32.4a	13.1b	35.2a	0.10b	0.18b	0.39b	0.46	63.9	37.6	53.5	34.7
Sesbania	11.1	27.1b	11.4c	30.4b	0.25a	0.30a	0.43a	0.51	59.1	29.1	54.7	40.9
Crotalaria	11.7	28.1b	17.6a	24.2c	0.33a	0.37a	0.48a	0.47	63.7	29.3	57.2	36.7
Mean	11.7	28.5	14.2	28.8	0.20	0.27	0.42	0.48	63.0	30.5	57.0	37.1
B. Ratio												
(Grass : legume)												
1 : 1	12.0	28.1	13.5	29.0	0.16	0.23	0.43	0.47	59.2	27.8	56.2	39.7
1 : 2	11.7	28.7	15.0	28.9	0.19	0.29	0.46	0.48	65.9	32.0	56.5	35.6
1 : 4	11.4	28.7	14.2	29.0	0.20	0.29	0.45	0.49	63.9	31.7	58.3	36.1

[1] Within columns for each main effect means followed by different letter are significantly different ($P < 0.05$)

contents, respectively. From a practical point of view, farmers have to compromise between maximum yield and acceptable forage quality. These results suggested that an acceptable ratio (grass : legume) for intercropping between grass and legume was around 1:2. When the ratios increased above that level, both grass yield and total pasture yield substantially reduced with less compensation from the legume components. Furthermore, with the limitation of land areas for pasture development in Thailand (Unguro, 1990) high dry matter production per unit area is an important consideration. According to this recommended ratio, the pasture can support daily milk yield of 14 kg/hd (Tudsri *et al*., 2001) which is well above average daily milk production (9 – 10 kg/hd) in Thailand. This agreed with the previous finding of Tudsri *et al*. (2002) and Nyaata *et al*. (1998) who found that the 1:1 and 1:2 ratio between grass and legume were the most suitable in both Thailand and Kenya.

As expected, crude protein content in all legumes were much higher than in grass in both leaf and stem. Thus, integration of these legumes with napier effectively increased both yield and quality as previously reported by Sampet (1991), Nyaata *et al*. (1998), Tudsri *et al*. (2001), and Jantarasiri and Sampet (2003). However, legume species differed significantly in crude protein content especially in the leaf fractions. Pigeon pea exhibited the highest crude protein content (32.4 – 35.2 %) whereas the lowest values were for leucaena and crotalaria. These values were similar to those reported by Tudsri and Kaewkunya (2002) in leucaena. The level of crude protein content of napier grass when in association with pigeon pea and sesbania was below 7% which was a critical level for animal intake (Milford and Minson, 1966). Thus, the inclusion of these legume species with the grass was important in terms of animal feeding.

In terms of phosphorus content, both the grass and the legumes, only exceeded critical levels 0.20 and 0.34 % (Minson, 1975) required for beef and dairy cattle, respectively, at the third harvest. It worthed noting that the stem fraction of leucaena and pigeon pea had lower consistently phosphorus contents than the other legumes.

The ADF content in the stem of most of the legumes studied were higher than in the grass but the reverse was true for the leaf, indicating the higher nutritive value of these legume to the grass especially in the leucaena and crotalaria. Leaf is the first part to be selected by the grazing animal which, with its lower ADF content, is more digestible (Cowan *et al*., 1986)

There was no effect of grass to legume ratios on the chemical composition of all components of grass and legumes.

CONCLUSIONS

Integrating sesbania and crotalaria with Taiwan A25 could produce higher total dry matter yield than leucaena and pigeon pea but in such yields were only sustained for the first two to three cuts. Pigeon pea could be used as an alternative tree legume instead of leucaena. The recommended ratio between grass and legume was 1 : 2 for all legumes. In terms of herbage quality, it was found that pigeon pea showed a greater crude protein content than leucaena, sesbania and crotalaria. Leucaena and pigeon pea produced lower levels of phosphorus while the ADF content in the grass leaf showed the highest. There was no effect of grass : legume ratios on crude protein, phosphorus and ADF content in grass and all legumes.

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