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Effect of Dry Season Cutting Management on Subsequent Forage Yield and Quality of Ruzi (*Brachiaria ruziziensis*) and Dwarf Napier (*Pennisetum purpureum* L.) in Thailand

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ABSTRACT

A field study was conducted under rainfed conditions during 2002 – 2003 to determine the effect of dry season cutting management on the yield and quality of ruzi (*Brachiaria ruziziensis*) and dwarf napier (*Pennisetum purpureum*) grass during the dry season and the following wet season. The pastures were cut 1, 3, 6 times during the dry season and 7 times during the following wet season at 5 and 20 cms above ground level. The study was sited on a reddish brown sandy clay loam soil at Suwanvajokkasikit Field Crop Research Station in the Pakchong district of northeast Thailand.

During both dry and wet seasons, leaf production and total plant production of dwarf napier were noticeably higher than ruzi grass but similar in stem production. Lax cutting (20 cm) produced significantly higher yield than close cutting (5 cm) and cutting every 2 months (3 times) tended to give higher yields than cutting more and less frequently of dwarf napier grass but not of ruzi. However, in the following wet season the pastures cut only once during the dry season produced significantly higher yields of herbage than those defoliation more frequently, particularly in the case of dwarf napier.

The protein percentage in dwarf napier and ruzi grass was not significantly different, although tended to be higher in dwarf napier particularly during the wet season and in the stem fraction. Protein yields, however, between the two grasses were highly significant with dwarf napier yield being much higher than ruzi, which was largely a reflection of the respective dry matter yields. Both pasture species showed higher protein yields under lax cutting than close cutting in both seasons.

Lax cutting also tended to produce higher neutral detergent fiber (NDF) and acid detergent fiber (ADF) content in the total herbage than close cutting and in both seasons. NDF and ADF concentration significantly increased with delayed time of cutting in the dry season.

Key words: dwarf napier, ruzi, cutting height, forage yield, dry season

INTRODUCTION

Most of the ruminant animals in Thailand raised on natural pastures and local dairy farmers, in particular, are keen to improve their pasture in order to achieve better economic milk production. Tudsri et *al*. (2002) noted that the grass species most commonly used on these dairy farms were para (*Brachiaria mutica*), ruzi (*B. ruziziensis*), guinea (*Panicum maximum*) and napier grass (*Penisetum purpureum*). At present, most of these grasses are cut and fed fresh to livestock or

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conserved rather than grazed. The reason given is that cut pasture gives the higher production although this has been clearly reflected by research conducted at D.P.O. (Hongyantarachai *et al*., 1989). Another factor is a lack of effective fencing.

Grazing or cutting management plays an important role in determining yield, quality and longevity of the pasture, and hence several workers have experimented in this area. For example, Tudsri *et al*. (2002) reported that grassland farmers tended to cut or graze their pasture to a very low level (0 – 10 cm) from the beginning of wet season and continued throughout the drought period. This may lead to a reduction in pasture yield during subsequent regrowth in the following wet season. These authors further suggested that optimum cutting height for all napier cultivars should not be lower than 20 cms in order to achieve good and quick regrowth. Tudsri and Kongsanor (1992) also showed that under severe water stress, cutting of dwarf napier grass resulted in death of all plants and no regrowth was observed after rewatering. Hard cutting under mild water stress also led to a considerable reduction in plant growth and dry weight relative to the lax cutting. In later work at Pakchong, Tudsri *et al*. (2002) showed that delaying the closing date of the pasture into the dry season produced a negative effect on regrowth in the following season, especially when a low cutting height had been imposed. Thus, a better understanding of cutting management during the drought period (November – April) is essential to improve dry season production and also reduce the effect of drought on subsequent pasture production. The experiment was designed to compare the two grass species, ruzi (*Brachiaria ruziziensis*) and dwarf napier, (*Pennisetum purpureum*) under different cutting management during the dry period (November- April) and these effects were examined in the following wet season in terms of herbage yield and quality for ruminant livestock production.

MATERIALS AND METHODS

The field experiment was conducted at Pakchong district, Nakhon Ratchasima province, The Suwanvajokkasikit Field Crop Research Station, Thailand, approximately 150 km northeast of Bangkok (14.5° N in latitude and 101° E in longitude, at an altitude of 360 m asl). Soil type of the experimental area was classified as a moderate reddish brown lateritic soil. Chemical content of the soil in the top 0 –15 cm of the trial site was 1.44% organic matter, 52.4 ppm available phosphorus (P) and 125.8 ppm available potassium (K) with a mean pH of 6.12.

The experiment was a split-split plot in a randomized complete block design and replicated four times. The two grass species were main plots. Sub plots were two cutting heights: 5 and 20cms. Sub-sub plots were three dry season cutting management: - 1) every month started from November – April, 2) in November, January and April, and 3) only once in April. The size of each plot was 2m × 2.5m. Two tropical perennial grass dwarf napier (*Pennisetum purpureum*) and ruzi grass (*Brachiaria ruziziensis* cv. Kennedy) were used for this experiment. Ruzi grass seeds and stem cuttings of dwarf napier grass bearing two nodes were planted in small plastic pots in June 2002. The resulting seedlings were watered daily until they reached the required height for planting (20 – 30cm). The seedlings were then transplanted to the field in August 2002. Seedlings were planted in rows 50cm apart with 50cm between plants and within the rows. Individual plots consisted of five 2.5m long rows spacing 0.5m apart. Each row contained 6 plants for a total of 30 plants per plot. Fertilizer was applied twice, initially with a basal compound fertilizer dressing of NPK (15-15-15) at the rate of 300 kg /ha and at the time of transplanting on August 8/ 2002, and again (15:15:15) at the rate of 30 kg/rai (187.5 kg/ha) and 10kg N/ rai (62.5 kg N/ha) as urea, on 1st May 2003 at the onset of rainy season.

In the dry season, forage was cut monthly, bimonthly and left uncut until the first week of April to the appropriate cutting height (5 and 20 cms).

In the wet season, each plot was cut manually with a sickle every month (started May 2003) to the treatment stubble heights of 5 and 20 cms above ground. The total biomas was weighed in the field and a representative fresh sub – samples of 300 – 400 gm was brougth to the weighing room, hand sorted into leaf and stem components. Dry matter of leaf and stem was determined by drying at 60°C for 72 hours (three days) in a drying oven. The sample weight obtained after drying leaf and stem was expressed in ton/hectare to determine dry matter yields. Dried samples were then ground with a mill to pass a 1mm sieve, and kept for chemical analysis.

Duplicate forage samples per treatment harvested in the last month of the dry season (April) and the wet season cutting (July) were subsequently analyzed to determine nitrogen (N), neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations. Total nitrogen was determined by micro Kjeldahl method (AOAC, 1975). Crude protein (CP) was calculated as % N x 6.25, and protein yield was estimated by calculation. NDF and ADF were determined according to the procedure described by Goering and Van Soest (1970).

The data were analyzed for significant differences among various treatments by analysis of variance using SAS statistical computer package Ver. 6.12 (SAS 1996). Duncan's Multiple Range Test (DMRT) was employed to compare the treatment means for different parameters and their significances at $P < 0.05$.

RESULTS AND DISCUSSION

Climatic conditions

Monthly rainfalls and monthly mean maximum and minimum air temperatures at the experimental site during the experimental period in 2002 and 2003 are presented in Figure 1. Temperatures were quite similar over both years.

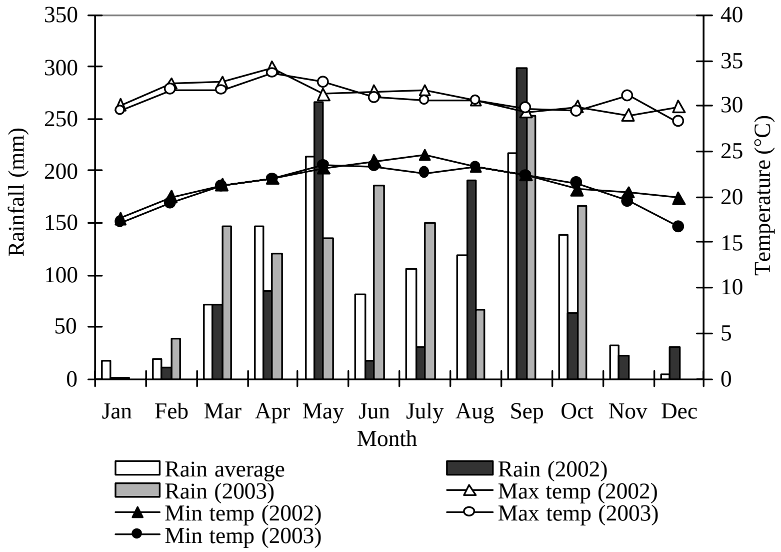

Figure 1 Medium term mean rainfalls (1996-2003) (rain average), monthly rainfalls (rain) and mean monthly maximum and minimum temperatures (max temp and min temp) in 2002-2003 at the Pakchong research site.

Rainfall obtained at the experimental site in the wet season of 2002 (May to October) was equal to the mid term average. The trend of rainfall pattern showed a linear increase from June to September and then declined in October in the same manner as the mid term mean. The unusual rainfalls recorded in December 2002 and February and March 2003 of the dry season were above the average and exceeded it by approximately 8%. The actual and average rainfalls received were higher in the months of March and April than the other months of the dry season. This had an impact on and was accounted for the tremendous increase of forage production harvested in early April. The amount of rainfall received in the wet season of 2003 was adequate and evenly distributed particularly in the last wet period of September and October. The total amounts of rainfall at the experimental site were 1085mm in 2002 and 1264mm in 2003 compared with the eight–year average of 1164mm.

Dry matter production

The main effects of grass species, cutting height and dry season cutting management on dry matter production during both the dry and wet seasons are presented in Table 1. As shown, the dry season production of dwarf napier was significantly greater than that of ruzi grass in terms of both leaf and total yield, but not in terms of stem yield. This agreed with the findings of Tudsri and Kaewkunya (2002) who showed that dwarf napier produced consistently greater dry matter yield and higher leaf percentage than ruzi under both mixed and pure swards.

Swards cut at 20 cm generally gave higher leaf, stem and whole plant yields than when cut at 5 cm, but this effect only reached significance in dwarf napier (Table 2a). It is possible that the relatively low growing, spreading habit of ruzi grass with its relatively short rhizomes compared with the erect habit of dwarf napier (Skerman and Riverose, 1990) may be accounted for this difference in response to cutting heights imposed. The growth habit of ruzi could make it more tolerant to close cutting whereas the erect habit of dwarf napier could well suffer from low residual leaf area after cutting for regrowth (Tudsri, 1986).

There were also significant interactions recorded between dry season cutting management and grass species and between dry season cutting management and cutting height (Table 2b and 2c). As shown, the approximate bimonthly (3 cuts) cutting of dwarf napier produced the highest yield but ruzi showed no significant difference in yield to the different dry season cutting management. Also the dry matter yield recorded in the different dry season cutting treatments showed no significant difference if cut to 5 cm, but when cut to 20 cm the single dry season cut in April was less than the two cutting treatments.

As shown in the higher order interaction in Table 3, the greater productivity recorded in the bimonthly dry season cutting treatment was very different in dwarf napier grass and particularly when cut lax (20 cm). In contrast, ruzi grass appeared quite tolerant of frequent cutting (monthly), but less only if cut laxly (20 cm). As mentioned above the differing growth habits of the two grasses possibly accounts for much of the response obtained particularly under frequent defoliation, whereas the significant time differences in the age of the respective swards ranging from 1 month (cut monthly) to almost 6 months (cut once) would probably produce considerable losses in dead matter particularly in the more prostrate swards of ruzi.

In the following wet season, dry matter yield increased substantially in both grasses due no doubt to ample rainfall and better weather conditions for growth. Dwarf napier produced significantly more leave than ruzi although the superiority in terms of whole plant yield failed to reach significance (Table 1). As in the dry season, there was no significant effect on stem production of the two grasses.

Table 1 Main effects of grass species, cutting height and dry season cutting management on mean dm yield (t/ha) of leaf, stem, whole plant and percent leaf, of dwarf napier and ruzi grasses in dry and wet seasons, of 2002 and 2003.

	Leaf	Stem	Whole plant	Leaf %
Dry season				
A. Species				
Dwarf napier	12.23[a2]	8.60	20.84[a]	58.53[a]
Ruzi grass	9.65[b]	8.79	18.44[b]	52.25[b]
B. Cutting height				
5	10.42[b]	8.05[b]	18.47[b]	56.30
20	11.46[a]	9.34[a]	20.80[a]	54.79
C. Dry season cut[1]				
1 (6 cut)	10.74[b]	8.41[b]	19.15[b]	56.10[a]
2 (3 cut)	11.83[a]	9.14[a]	20.97[a]	56.13[a]
3 (1 cut)	10.25[b]	8.53[b]	18.79[b]	54.40[b]
Wet season				
A. Species				
Dwarf napier	18.91[a]	11.82	30.73	61.43[a]
Ruzi grass	13.71[b]	10.78	24.49	56.06[b]
B. Cutting height				
5	15.34[b]	10.54[b]	25.88[b]	58.89[a]
20	17.27[a]	12.06[a]	29.34[a]	58.60[a]
C. Dry season cut[1]				
1	15.82[b]	10.99[b]	26.81[b]	58.77
2	15.46[b]	10.76[b]	26.22[b]	58.73
3	17.65[a]	12.15[a]	29.80[a]	58.73

Interaction:				
Dry Season	Leaf	Stem	Total	Leaf(%)
A	**	ns	**	**
B	**	**	**	ns
A x B	ns	*	*	ns
C	**	*	**	*
A x C	**	*	**	*
B x C	*	**	**	ns
A x B x C	**	**	**	*
Wet Season				
A	*	ns	ns	**
B	**	**	**	ns
A x B	**	**	**	ns
C	*	ns	*	ns
A x C	ns	ns	ns	ns
B x C	ns	ns	ns	ns
A x B x C	ns	ns	ns	ns

1 Dry season cutting, 1 = cut every month from Nov to April, 2 = Cut in Nov, Jan and April, 3 = cut only once in April.

2 Within columns for each main effect and season, means followed by the different letters are significantly different ($p<0.05$).

Table 2 Mean whole plant dry matter yields (t/ha) of species x cutting height (a) species x dry season cut (b), and cutting height x dry season cut (c) interaction effect in the dry season harvest of 2002 and 2003.

(a) Species x Cutting height interaction

Species	Cutting height (cm) 5	20	Mean
Dwarf napier	19.12^{b1}	22.55^{a}	20.84^{A2}
Ruzi grass	17.83^{b}	19.05^{b}	18.44^{B}
Mean	18.47^{b}	20.80^{a}	

(b) Species x Dry season cut

Species	Dry season cutting management 1	2	3	Mean
Dwarf napier	19.30^{b}	23.42^{a}	19.80^{b}	20.84^{A}
Ruzi grass	19.02^{b}	18.53^{b}	17.78^{b}	18.44^{B}
Mean	16.15^{b}	20.97^{a}	18.79^{b}	

(c) Cutting height x Dry season cut

Cutting height (cm)	Dry season cutting management 1	2	3	Mean
5	17.23^{b}	19.21^{b}	18.99^{b}	18.47^{B}
20	21.09^{a}	22.74^{a}	18.59^{b}	20.80^{A}
Mean	19.15^{b}	20.97^{a}	18.79^{b}	

[1] Within rows means followed by different small letters are significantly different (p<0.05).
[2] Within columns means followed by the different capital letters are significantly different (p<0.05).

Table 3 Effect of grass species, cutting height and dry season cutting management on whole plant dry matter yield (t/ha) dwarf napier and ruzi grasses in dry season, of 2002 and 2003.

Dry season Cutting management	Dwarf napier		Ruzi		Mean
	Cutting height (cm)				
	5	20	5	20	
1. Cut every month	17.98^{b1}	20.61^{b}	16.47^{b}	21.56^{a}	19.15^{b}
2. Cut three times	20.41^{a}	26.43^{a}	18.01^{a}	19.04^{b}	20.97^{a}
3. Cut only once in April	18.98^{b}	20.61^{b}	19.00^{a}	16.56^{c}	18.79^{b}
Mean	19.12^{B2}	22.55^{A}	17.83^{B}	19.05^{B}	

[1] Within columns means followed by different small letters are significantly different (p<0.05)
[2] Within rows means followed by different capital letters are significantly different (p<0.05)

This leafiness of dwarf napier supported the earlier work of Tudsri *et al*. (2002) and Sukkagate *et al*. (1997) where dwarf napier produced a higher leaf: stem ratio than ruzi, purple guinea and para grass over a wide range of maturity. According to Beaty and Engel (1980), such cultivars high in leaf content were much higher in quality than cultivars that produced more stems.

Swards cut at 20 cm produced more leaves and stems and achieved higher whole plant yield than swards cut at 5 cm and as shown in Table 4, this only reached significance in the dwarf napier swards. This finding agreed with that of Tudsri *et al*. (2002) in his work with cultivars of napier grass and that of Goonewardena *et al*. (1984) working with *Panicum maximum*. These latters further stated that lenient cutting favored the persistence of erect growing grasses such as *Panicum maximum*, but if cut or grazed intensively they were short – lived and became invaded by weeds and required frequent replanting.

Whole plant production increased markedly when only cut once during the dry season compared with the lower production from more frequent cutting in the dry season. This was apparent in both the leaf and stem fractions and hence in total production. This yield difference was possibly due to the accumulation of carbohydrate plant reserves built up during the previous dry season when this treatment was left uncut almost for 6 months.

Chemical composition

There were no significant effects of grass species or cutting height on the crude protein concentration in the leaf, stem or whole plant in either the dry or wet seasons (Table 5). However, there was a general decline in crude protein concentration, especially in the dry season, with increasing length of cutting interval. This was similar to results obtained elsewhere in Thailand with ruzi (Kasantikul, 1993) and napier grass (Sukkagate, 1994). It was worth noting, however, that the crude protein levels recorded in this experiment were consistently above the level expected to impair animal production as Milford and Minson (1966) showed that intake was only reduced if crude protein of the forage was less than 7%. As reported for most grasses, both tropical and temperate, leaves contain noticeably higher concentrations of crude protein than stems.

There were highly significant differences recorded in crude protein yield between dwarf napier and ruzi, between 5 cm and 20 cm cutting heights and between dry season cutting management treatments (Table 5). However, these differences were largely a reflection of difference in dry matter yield already presented. The only response of significance from the generalization was in the protein yields recorded during the dry season from close cutting (5 cm) of dwarf napier and ruzi. While dwarf napier benefited significantly from lax cutting, ruzi grass showed no difference

Table 4 Mean whole plant dry matter yields (t/ha) of species x cutting height interaction effect in the wet season 2003.

Species	Cutting height (cm)		Mean
	5	20	
Dwarf napier	29.87[a2]	31.60[a]	30.73[a1]
Ruzi	21.90[b]	27.08[a]	24.96[b]

1 Within columns means followed by different letters are significantly different (p<0.05).
2 Within rows means followed by different letters are significantly different (p<0.05).

Table 5 Mean crude protein concentrations (%) and crude protein yields (kg/ha) of leaf, stem and whole plant of dwarf napier and ruzi grass as affected by forage species, cutting height and cutting management in dry and wet seasons, of 2002 and 2003.

	Crude protein content (%)			Crude protein yield (kg/ha)		
	Leaf	Stem	Whole plant	Leaf	Stem	Whole plant
Dry season (April)						
A. Species						
Dwarf Napier	11.5	11.4	11.6	1411.9[a]	1025.9[a]	2415.0[a]
Ruzi grass	12.6	7.6	10.3	1214.8[b]	620.3[b]	1875.3[b]
B. Cutting height						
5	12.4	9.6	11.1	1346.0	714.4[b]	2020.1
20	11.8	9.5	10.7	1280.8	931.8[a]	2270.1
C. Dry season cut[1]						
1	13.6[a]	10.4	12.9[a]	1458.1[a]	876.99[a]	2477.0[a]
2	11.0[b]	9.4	10.2[b]	1308.2[b]	871.3[a]	2184.1[b]
3	11.6[b]	8.8	9.6[b]	1173.8[c]	721.2[b]	1774.2[c]
Wet Season (July)						
A. Species						
Dwarf Napier	13.9	11.0	13.1	2639.0[a]	1232.6[a]	3990.1[a]
Ruzi grass	11.3	7.4	9.8	1556.8[b]	802.4[b]	2403.2[b]
B. Cutting height						
5	12.5	9.0	11.1	1948.1[b]	916.0[b]	2911.2[b]
20	12.7	9.4	11.7	2247.7[a]	1119.0[a]	3482.1[a]
C. Dry season cut						
1	12.5	9.4	11.6	1996.1[b]	1003.4[b]	3098.3
2	12.9	9.0	11.6	2040.7[b]	920.2[b]	3082.3
3	12.4	9.2	11.2	2257.0[a]	1128.9[a]	3409.3
Significance:						
Dry Season (April)	Leaf	Stem	Total	Leaf	Stem	Total
A	ns	ns	ns	**	**	**
B	ns	ns	ns	ns	**	**
A x B	ns	ns	ns	ns	**	**
C	**	ns	**	**	**	**
A x C	ns	ns	ns	**	**	**
B x C	*	ns	ns	**	ns	**
A x B x C	ns	ns	ns	**	**	**
Wet Season (July)						
A	ns	ns	ns	*	*	*
B	ns	ns	ns	**	**	**
A x B	ns	ns	ns	ns	ns	ns
C	ns	ns	ns	*	**	ns
A x C	ns	ns	ns	*	*	ns
B x C	*	ns	ns	ns	**	**
A x B x C	ns	ns	ns	ns	*	*

[1] Dry season cutting management 1 = cut every month from Nov to April, 2 = cut in Nov, Jan and April, 3 = cut only once in April.

[2] Within columns for each main effect and season, means followed by different letters are significantly different ($p<0.05$)

in protein yield when close or lax. This was most apparent during the dry season but not so conclusive during the wet season.

As shown in Table 6, the leaf of dwarf napier grass, grown during the dry season, had significantly higher percentages of NDF and ADF than the leaf of ruzi grass. However, this superiority was not reflected in the whole plant and was not evident during the wet season.

Plants cut at 20 cm tended to have higher NDF and ADF than those cut at 5 cm particularly during the dry season. NDF and ADF contents of the whole plant also increased significantly with less frequent cutting, particularly, in the stem fraction, but was not apparent in the wet season.

CONCLUSIONS

The finding from this study suggested that dwarf napier produced more yield and greater percentage of leaf than ruzi grass in both dry and wet seasons. Both dwarf napier and ruzi produced better yield at 20 cm than 5 cm cutting height in the dry season as well as in the wet season.

Table 6 Mean neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations in leaves, stems and whole plants of dwarf napier and ruzi grass in dry and wet seasons, of 2002 and 2003.

	NDF %			ADF %		
	Leaf	Stem	Whole plant	Leaf	Stem	Whole plant
Dry season (April)						
Species						
Dwarf napier	60.7[a2]	64.5	61.9	34.7[a]	38.3	36.1
Ruzi grass	55.0[b]	66.9	60.7	27.0[b]	36.4	31.7
Cutting ht						
5	56.3	64.1	60.1	30.1	36.6	33.4
20	59.4	67.3	62.5	31.6	38.1	34.3
Dry season cut[1]						
1	57.2	63.3[b]	58.4[b]	30.1	33.9[b]	30.8[b]
2	57.4	62.8[b]	59.4[b]	31.2	34.3[b]	32.4[b]
3	58.9	71.0[a]	66.1[a]	31.2	43.8[a]	38.4[a]
Wet season (July)						
Species						
Dwarf napier	54.6	61.0	55.8	32.1	37.0	32.9
Ruzi grass	54.9	64.5	58.2	28.9	36.6	31.5
Cutting ht (cm)						
5	54.8	62.3	56.9	30.2	35.8	31.9
20	54.7	63.2	57.1	30.8	36.8	32.6
Dry season cut						
1	54.4	62.2	56.6	30.2	35.9	31.9
2	55.0	63.9	57.3	30.5	36.8	32.2
3	54.9	62.2	57.1	30.9	36.1	32.5

1 Dry season cutting, 1= cut every month from Nov to April, 2 = Cut in Nov, mid Jan and April, 3 = Cut only in April.
2 Within columns for each main effect and season, means followed by the different letters are significantly different ($p<.0.05$)

Pasture management in the dry season made considerable contribution to increased forage and protein yield in the following wet season. Hence, the farmers should refrain from frequent cutting of their pasture in the dry season if they desire to produce maximum yield and get maximum benefit from their pasture in the subsequent wet season. However, if the farmers need to use their pastures in the dry season then, lax cutting at 20 cms is recommended.

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LITERATURE CITED

AOAC. 1975.**Official Methods of Analysis** (12th ed.). Association of Official Analytical Chemists, Washington, DC. 58 (4): 811-817.

Beaty E. R., and J. L. Engel.1980. Forage quality measurements and forage research –A review, Critique and interpretation. **J. Range Management** 33 (1): 49-54.

Goering H. K. and P. J. Van Soest. 1970. Forage fiber analysis (apparatus, reagents, procedures and some application), pp. 1-120. *In* **Agric. Handbook 379**, ARS, USDA, Washington, DC.

Goonewardena L. A., K. Nadarajah, V. Ravindran and S. Panditharatne. 1984. Effect of nitrogen application, defoliation intensity and defoliation frequency on the yield and feeding value of *Panicum maximum* Jacq (Guinea A) fodder. **Beitrage Zur Tropischen Landwirtshaft und Veterinarmedizin**. 22: 383-389.

Hongyantarachai, S., G. Nithichai, N. Wongsuwan, S. Prasanpanich, S. Siwichai, S. Pratumsuwan, T. Tasapanon and B. R. Watkin.1989. The effects of grazing versus indoor feeding during the day on milk production in Thailand. **Trop. Grassl**. 23: 8-14.

Kasantikul, V. 1993. **Studies on yield and quality of some tropical pasture grasses and legumes at different stage of growth**. M.S. thesis. Kasetsart University, Bangkok.

Milford, R. and D. J. Minson, 1966. The feeding value of tropical pasture,. pp.106-114 *In* E. W. Davies and C. L. Skidmore. (eds.). **Tropical Pastures**. Faber and Faber, London

Phaikaew C. and P. Pholsen. 1993. Ruzi grass (*Brachiaria ruziziensis*) seed production and research in Thailand. *In* C. Chen and C. Statjipanon (eds.). Strategies for suitable forage based livestock production in Southeast Asia. **Proc. of the 3rd meeting of regional working group on grazing and feed resources of Southeast Asia** 31 January – 6 February 1993, Khon Kaen Thailand.

SAS institute Inc., 1996. SAS/ **STAT User's Guide, Release 6.12 edition**. Statistical analysis systems institute inc., Cary, NC, USA.

Skerman, P. J. and F. Riveros.1990. **Tropical Grasses**. FAO. Plant production and protection series No. 29. Rome. 832 p.

Sukkagate, S. 1994. **Effects of defoliation frequency on yield and quality of four different growth habit grasses**. M. S. Thesis. Kasetsart University, Bangkok.

Tiley G. E. D. 1989. Factors affecting the productivity of elephant grass. **Proc. of the XVI international grassland congress**, Nice, France, 599-60.

Tudsri S. and C. Kaewkunya. 2002. Effect of leucaena row spacing and cutting intensity on the growth of leucaena and three associated grasses in Thailand. **Asian Aust. J. Anim. Sci.** 15 (7): 986-991.

Tudsri S., T. Jorgenson, P. Ridach and A. Pookpakdi. 2002. Effect of cutting height and dry season closing date on yield and quality of five napier grass cultivars in Thailand. **Trop. Grassl**. 36: 248-252.

Tudsri, S. and Kangsanor, M. 1994. Effect of water stress and cutting height on dwarf napier Grass (*Pennisetum purpureum* CV. Mott). **Paper presented at the 32nd Kasetsart University Conference** 3-5 February 1994, Bangkok, Thailand.

Tudsri, S. 1986. **A study of the effects of defoliation and water stress on growth and development of *Stylosanthes hamata* (L.) Taub. CV. Verano**. Ph.D. Thesis, Massey University.