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Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

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Effect of Cutting Heights on Productivity and Quality of King Napier Grass (*Pennisetum purpureum* cv. King Grass) under Irrigation

Sumran Wijitphan[1], Pornchai Lorwilai[2] and Chutipong Arkaseang[2]
[1]Khon Kaen Animal Nutrition Research and Development Center,
T. Thra Pra A. Muang Khon Kaen, 40260, Thailand
[2]Faculty of Agriculture, Khon Kaen University, P.O. Box 40002, Thailand

Abstract: An experiment to study the effect of cutting heights on yield and nutritive values of King napier grass (*Pennisetum purpureum* cv. King grass) was conducted on sandy loam, Korat soil series (Oxic Paleustults) under irrigation during June 2006 to November 2007 at Khon Kaen Animal Nutrition Development Research Center, Thailand. Four treatments of cutting height at 0 (T1), 5 (T2), 10 (T3) and 15 (T4) cm above ground level in randomized complete block design with 4 replications were employed. The results showed that the Total Dry Matter Yield (TDMY) and Average Dry Matter Yield (ADMY) (65,707.5, 67,070.0, 69,697.5 and 71,403.1 kg/ha/year ; 5,973.4, 6,096.4, 6,336.2 and 6,491.2 kg/ha/cut, respectively) were significantly higher ($p<0.05$) in T4 than T1. There were no significant differences in CP and DMD among treatments, ranging from 12.1-12.9 and 75.5-76.6%, respectively but the percentage of ADF, NDF and ash were highly significantly different (41.7-43.5, 64.6-66.2 and 13.1-14.7%), respectively. Based on this research, it can be concluded that cutting height can affect the forage DM yield and nutritive values of King Napier grass. Cutting 35 day interval at 15 cm height above ground level could be the optimal level for harvesting King Napier grass in Northeast of Thailand.

Key words: Cutting height, dry matter yield, irrigation, king napier grass, nutritive values

INTRODUCTION

Napier grass (*Pennisetum purpureum* Schum.) is a perennial forage crop with high growth rate, high productivity and good nutritive value and mostly used for cut and carry system over the tropical and sub-tropical area of the world (Cook *et al*., 2005; Duke, 1983; Wadi *et al*., 2004; Santos *et al*., 2001b). The various cutting studies with elephant grass revealed that both the choice of cutting interval and height of cutting are crucial to their performance and found that the main factor affecting growth, yield and persistence of swards is the defoliation intensity (Werner *et al*., 1966; Santana *et al*., 1989; Santos *et al*., 2001b and Wadi *et al*., 2004). The severity of defoliation causes physiological and morphological changes at plant level, especially during the regrowth period (Briske, 1986).

The regrowth after defoliation is one of the most important physiological processes and it determines the sward structure (Matthew *et al*., 1995). However, herbage yield was affected by the cutting height and depend on growth character of plant or plant type and climatic condition, also. Cutting near the ground level increase total and seasonal forage production over a short period as compared to more elevated cutting heights, but plants are adversely affected as the same way as to frequent harvesting (Crowder and Chheda, 1982). Because they lost the growing point and reduced storage carbohydrate in the subterranean stem of stubble tillers (Humphreys, 1974; Ollerenshaw and Hodgson, 1977; Whiteman, 1980; Ezenwa and Aken'Ova, 1996 and Trujillo *et al*., 1996). However, there are many research works on the cutting height of Napier grass showed the uncertainty results. Thinnakorn *et al*. (1995) found no difference in the production of the Napier grass cut 30-35 day interval at 5, 10 and 15 cm; whereas, Caro-costor and Vincente-Chandler (1961) worked in Puerto Rico found that cutting the elephant grass at lower level obtained higher dry matter yield than cut at higher level; Gonçalves and Coast (1991) obtained variation in the annual production of herbage dry matter of about 19.69-25.29 t /ha on average, when varying the height of cut at 5-30 cm above the ground level. In addition to, there are adversely interaction between cutting frequency and height. High DMY may be achieved by cutting more often with higher of cutting height, whereas lower of cutting height with longer cutting intervals may get high DMY as well. Because low level cutting may loose more photosynthetic part and need to use longer time for regrowth than the higher level of cutting (Walton, 1984).

According to Wadi *et al*. (2004) found that Napier grass cut at a 30 cm height was superior to that of the grass cut at 0 cm height, when cut at 90 days interval, but the annual Herbage Dry Matter Yield (HDMY) was higher in the grasses at a 90 day interval and 0 cm height than at a 60 day interval and 30 cm height. With regard to grass quality, Nakamanee *et al*. (1996) reported that cutting at 0, 7.5 and 15 cm were not significant effect on CP

content and %ADF, but significantly different in %NDF of Napier grass. Although Werner *et al.* (1966) have obtained very high protein levels (19.97 and 18.17%, with cutting close to the ground and 15-20 cm, respectively). However, several other studies showed that the crude protein content of the elephant grass commonly ranges from 3.4-12.9%, according to climatic condition and age of cutting (Silveira *et al.*, 1974; Gonçales, 1985; Aveiro *et al.*, 1991; Gonçalves and Coast, 1991; Santos, 1994). This study was conducted to investigate the effect of cutting heights on productivity and quality of King Napier grass (*Pennisetum purpureum* cv. King grass) under irrigation.

MATERIALS AND METHODS

Location and climate of the experimental site: Field experiment was conducted under irrigation during March 2006 to November 2007 at Khon Kaen Animal Nutrition Research and Development Center in Northeast, Thailand (16°00' N, 102°30' E; elevation 1,150 m). The soil is a sandy loam, Korat soil series (Oxic Paleustals). Temperature and precipitation data were obtained from the Thapra Agro-Meteorological Station, located about 1 km north of the experiment site.

Experimental design and treatments: Four treatments of cutting height at 0 (T1), 5 (T2), 10 (T3) and 15 (T4) cm above ground level in randomized complete block design with 4 replications were employed.

Crop cultivation and maintenance: The experimental site was plowed in late March 2006. Soil samples were taken from depths of 0-15 cm as composites of four samples from four random locations within each plot. Limestone was applied at 937.5 kg/ha based on the soil analysis, before planting 7 days. The basal fertilizer with 625 kg/ha of 15-15-15 fertilizer and 6.25 t/ha of cattle manure were provided to the experimental plots. Planting King Napier grass by stem cutting with 2 nodes a piece and placed 45° with 2 pieces a hole with plant spacing of 50 x 80 cm in 3 x 4 m plot size. Each plot was applied urea at 125 kg/ha after each cutting and applied cattle manure at 1,562.5 kg/ha every 3 months. The entire plot area was kept weed-free with hand hoeing after cutting and irrigated whenever necessary.

Data collection and harvesting: In order to standardize, all plots were cut at 70 days after planting without data collection. To minimize the effect of border row, all samples were taken from the 2 x 3 m strip perpendicular to the row direction of each plot every 35 days for DMY 11 times by cutting height followed the treatments. Twelve plants were selected randomly from the central two rows and the following growth variables were recorded for each plot; height of plants, number of tillers.

Chemical analyses: The plant samples were analyzed for Crude Protein (CP) (AOAC, 1984), ADF and NDF (Goering and Van Soest, 1970) and Dry Matter Digestibility (DMD) by nylon bag technique (Orskov, 1982).

Statistical analyses: The analysis of variance was performed and compared treatment mean by DMRT (Steel and Torrie, 1960) by using GLM Procedure of SAS statistical computer package Ver. 6.12 (SAS, 1998).

RESULTS AND DISCUSSION

Climatic conditions: The climatic data of monthly mean rainfall, maximum and minimum air temperatures throughout the growing season of this study are shown in Table 1. Total precipitation, monthly mean minimum and maximum temperature during the experimental period in 2006 and 2007 were 1,415.5; 1,151.0 mm; 16.0; 24.7°C; 30.9; 36.2°C, respectively. Climatic conditions in the Northeast Thailand were generally considered to be good for Napier grass growth and forage yielding. The climatic data of the present study are consistent with Cook *et al.* (2005) and JLTA (1996) who quoted that the optimum growth temperature of Napier grass is between 25-40°C and little growth below about 15°C, with stop growing at 10°C, but re-grow with onset of warm and moist condition. During this study the temperature declined to 16°C during December, 2006 to January, 2007 and in some days closed to 10°C, which are likely to be having a major affect on stop growing of the grass. After then the maximum temperature at 36.2°C and 36.1 C. in March and April, 2007, respectively. The grass may storage carbohydrate in subterranean stem and regrowth very fast due to the optimum temperature, water supply and cattle manure application at that time.

Dry matter yield: Total Dry Matter Yield (TDMY) and Average Dry Matter Yield (ADMY) (65,707.5, 67,070.0, 69,697.5 and 71,403.1 kg/ha/year; 5,973.4, 6,096.4, 6,336.2 and 6,491.2 kg/ha/cut, respectively) were significantly higher ($p<0.05$) in T4 than T1. TDMY and ADMY were numerically highest for the T4 treatment (Table 2). The results of this study indicate that cutting height had significant effects on TDMY and ADMY of King Napier grass. The current results are in agreement with Werner *et al.* (1966) who reported that the annual DMY of Napier grass increased with increased the cutting height. They worked with 4 weeks of cutting interval and cutting at 1-3, 30-40 and 70-80 cm above the ground level which gave 4.5, 11.9 and 13.1 t DM/ha, respectively and Nakamanee *et al.* (1996) who found cutting at 7.5 and 15 cm above the ground level gave 2 year average DMY higher than cutting at 0 cm height. For the reason could be explained by Walton (1984) who stated that cutting near the ground level cause loose almost entirely

Table 1: Monthly weather data during the experimental period

	Rainfall (mm)		Max. temp (°C)		Min. temp (°C)	
Month	2006	2007	2006	2007	2006	2007
January	0.0	0.0	32.7	30.9	16.1	16.0
February	38.1	8.4	33.2	34.6	19.4	18.8
March	16.4	59.8	35.4	36.2	22.7	23.3
April	88.8	9.0	35.9	36.1	24.1	24.2
May	163.4	232.5	34.2	33.1	23.7	24.3
June	216.3	129.0	34.1	34.2	24.7	25.0
July	305.4	86.8	32.1	33.4	24.5	24.4
August	238.7	226.3	31.7	31.6	24.0	21.1
September	214.2	192.0	32.3	31.9	23.5	23.6
October	133.3	192.2	32.2	30.7	22.5	23.3
November	0.9	15.0	33.7	29.6	20.5	17.7
December	0.0	0.0	31.0	31.7	16.5	18.1
Total	1,415.5	1,151.0	-	-	-	-

Source: Thapra Agro-Meteorological Station, Khon Kaen (2007)

Table 2: Effect of cutting heights on dry matter yield of King Napier grass grown under irrigation

		Dry Matter Yield (kg/ha)					
Cutting No.	Cutting date	T_1 (0 cm)	T_2 (5 cm)	T_3 (10 cm)	T_4 (15 cm)	F -value	% C.V.
1st Cut	19/9/2006	8,897.5^{a}	7,888.7^{ab}	7,762.1^{ab}	6,696.6^{b}	*	9.21
2nd Cut	24/10/2006	5,027.6	4,857.8	5,812.1	4,835.6	NS	10.05
3rd Cut	28/11/2006	6,838.8	6,980.0	6,810.3	7,748.8	NS	6.96
4th Cut	2/1/2007	3,240.3	3,099.0	2,982.8	3,138.3	NS	12.09
5th Cut	6/2/2007	4,435.6^{a}	5,170.0^{b}	5,441.9^{b}	5,285.6^{b}	**	6.77
6th Cut	13/3/2007	6,825.6^{a}	6,707.6^{a}	7,488.9^{ab}	7,939.1^{b}	*	8.47
7th Cut	17/4/2007	6,173.5^{a}	6,266..6^{a}	6,843.4^{a}	8,011.9^{b}	**	8.66
8th Cut	22/5/2007	5,356.6^{a}	6,032.4^{ab}	6,240.1^{ab}	6.609.6^{b}	*	9.11
9th Cut	26/6/2007	8,017.8	8,380.4	7,857.6	8,019.4	NS	5.29
10th Cut	31/7/2007	5,431.3	4,997.1	5,458.7	4,941.7	NS	9.68
11th Cut	4/9/2007	5,462.7^{a}	6,680.4^{b}	6,999.6^{b}	8,176.5^{c}	*	6.86
Total	-	65,707.5^{a}	67,070.0^{ab}	69,697.5^{ab}	71,403.1^{b}	*	4.56
Average	-	5,973.4^{a}	6,096.4^{ab}	6,336.2^{ab}	6.491.2^{b}	*	4.56

Means within a row followed by the different letter are different ($p<0.05$).
NS = Non significant difference ($p>0.05$) ** = Highly significant difference ($p<0.01$)

of growing point or apical meristematic tissue, the photosynthetic part and the storage carbohydrate in the subterranean stem of stubble tillers. Consequently, the tillers might be died and the new ones grew instead from the lateral bud. So, the initials of plant regrowth were lower than the higher level of above ground cutting. However, these findings of the current study are inconsistent with Santana *et al.* (1989) studied the interaction between frequency and cutting height of 3 cultivars of Napier grass and concluded that the higher productivity was combining with cut to the ground at an 8 week interval. It can explain that the low level of cutting may loose more photosynthetic part and use more time for regrowth than the high level of cutting (Walton, 1984). In addition to Thinnakorn *et al.* (1995) who worked at Pakchong district, Thailand, whereas the soil was quite high fertility. They found that cutting at 5, 10 and 15-cm height at 30-35 days of cutting interval were no significant effects on average 2 year of DMY which obtained 12.00, 13.08 and 12.53 t/ha/year, respectively. It is noted that DMY of work done by Thinnakorn *et al.* (1995) was quite low compare with the current study. This might be due to irrigation and cattle manure was not practiced.

Table 1 showed DMY distribution of King Napier grass in one year round of 4 different cutting heights with 35 days cutting interval. Figure 1 showed the relation between DMY with air temperature. The DMY of current study was 71,403.1 kg/ha which sufficient for feeding 24 milking cows throughout the year (NRC, 2001). However, the distribution of DMY of Napier grass all year round was fluctuated, either lower or higher than requirement; in the 4th cut, a lower DMY (3,183.3 kg/ha) was obtained, whereas in the 11th cut an excess DMY (8,176.5 kg/ha) was obtained for example. Therefore, during the time that DMY was excess or lower than requirement of the cows. The amount of cutting area should be considered for determined the DMY of the grass.

Moreover, Wadi *et al.* (2004) reported that annual Herbage Dry Matter Yield (HDMY) of King Napier grass was higher in the plants at a 90 day interval and 0 cm height than at a 60 day interval and 30 cm cutting height. Tekletsadik *et al.* (2004) found that lax cutting (20 cm)

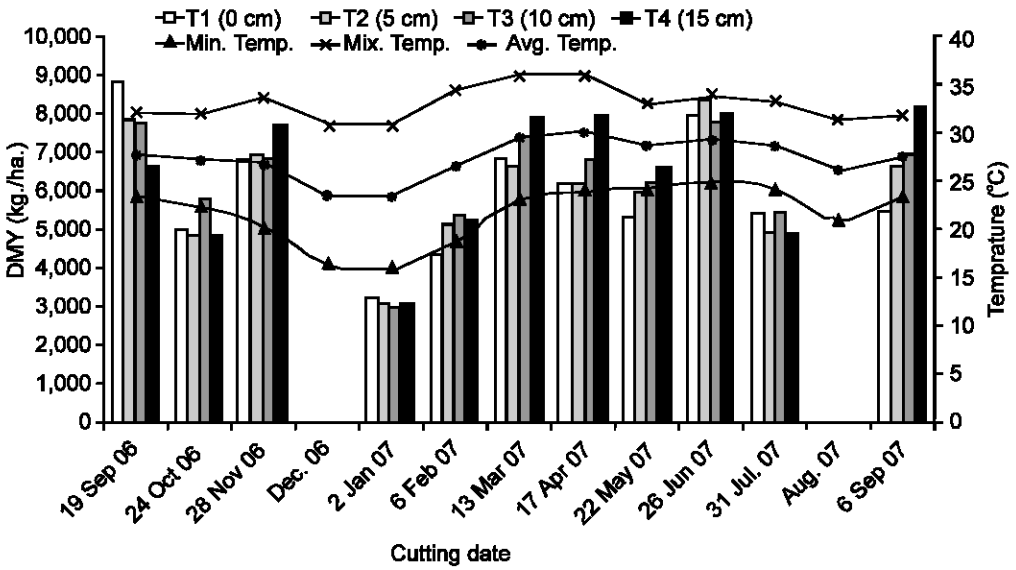

Fig. 1: Relationship between dry matter yield of King Napier grass with air temperature

produced significantly higher yield than close cutting (5 cm) and cutting every 2 months (3 times) tended to give higher yield than cutting more and less frequencies of dwarf Napier grass. So, the results of this present study indicated that DMY of King Napier grass greatly related to cutting height and cutting intervals. High DMY may be achieved by cutting more often with higher of cutting height, whereas lower of cutting height with longer cutting intervals may get high DMY as well. Because low level cutting may loose more photosynthetic part and use longer time for regrowth than the high level of cutting (Walton, 1984).

Nutritive values: There were no significant differences in CP and DMD among treatments, ranging from 12.1-12.9 and 75.5-76.6%, respectively. However, percentage of ADF, NDF (41.7, 43.5, 42.2 and 42.8; 64.6, 66.2, 65.6 and 65.4 %, respectively) were highly significantly higher ($p<0.01$) in T2, T3 and T4 compared with T1, but there was no significant difference among T2, T3 and T4; whereas, percentage of Ash (14.7, 13.3, 13.2 and 13.1%, respectively) were highly significantly lower ($p<0.01$) in T2, T3 and T4 compared with T1, but there was no significant difference among T2, T3 and T4 (Table 4).

The average of CP percentage of the current study were similar to the results of Santos *et al.* (2001a) and Nakamanee *et al.* (1996), who worked with the same cultivar in Chainat province, Thailand and obtained 8.9% CP. The average CP percentage of the present study was 12.4%. This CP value is higher than CP level in roughage that affects to animal's intake. Milford and Minson (1966) stated that the 7%CP was a critical level in the forage. If the CP content of the grass is less than 7%, it is factors limiting animal production due to low voluntary intake, lower rate of digestibility and negative nitrogen balance. The minimum level of protein in feed, to have adequate rumen fermentation, must contain 7%CP content (Minson, 1981).

The average fraction of ADF and NDF in this experiment were 41.9 and 72.3% and similar to Queiro Filho *et al.* (1998), who cut the Roxo elephant grass at the ground level with 40 day interval, received 41.6 and 71.8%, respectively. In addition to, Nakamanee *et al.* (1996) showed cutting King Napier grass at 0-15 cm height and 40 days cutting interval received the average of ADF and NDF were 44.9 and 69.0%. However, the fractions of NDF and ADF, which normally increase with age of the plant. Santos *et al.* (2001a) who found that cutting the Roxo elephant grass at 0, 15, 30, 45 cm height and 60 days interval obtained the averages of ADF and NDF were 42.75 and 76.41%, when the cutting interval extended to 90 days, the average of ADF and NDF decreased to 41.02% and 71.13%, respectively.

Although, the result showed that cutting height had different effect on ADF and NDF components. The forage quantity of this study were higher than animal requirement which recommended by NRC (2001), the forage crops should have ADF and NDF not less than 17% and 33 %, respectively. The different amount of ADF and NDF in forage crops depend on varieties and age of plant (Preston and Leng, 1987). The percentage of ash decreased with increasing level of cutting height. The current results are in agreement with Thinnakorn *et al.* (1995) who found that range of the ash content of King Napier grass were 14.3-15.4%, when cut at 5-15 cm height and 30-35 days of cutting interval.

Number of tillers and tiller weight: The effect of cutting heights on Number of Tillers (NT) and Mean Tiller Weight (MTW) of King Napier grass are presented in

Table 3: Effect of cutting heights on nutritive values of King Napier grass grown under irrigation (% On DM basis)

Cutting height	CP	ADF	NDF	Ash	DMD (nylon bag)
0 cm	12.4	41.7^{b}	64.6^{b}	14.7^{a}	76.6
5 cm	12.3	43.5^{a}	66.2^{a}	13.3^{b}	75.9
10 cm	12.1	42.2^{a}	65.6^{a}	13.2^{b}	75.7
15 cm	12.9	42.8^{a}	65.4^{a}	13.1^{b}	75.5
Average	12.4	42.3	65.5	13.6	79.9
F-Value	NS	**	**	**	NS
CV (%)	3.00	0.65	0.80	2.89	0.90

Means within a row followed by the different letter are different ($p<0.05$)
NS = Non significant difference ($p>0.05$) ** = Highly significant difference ($p<0.01$)

Table 4: Effect of cutting heights on Number of Tillers (NT) and Mean Tiller Weight (MTW) of King Napier grass grown under irrigation

		NT (tillers/m^2)				MTW (g/tiller)			
Cutting No.	Cutting date	0 cm	5 cm	10 cm	15 cm	0 cm	5 cm	10 cm	15 cm
1st Cut	19/9/06	65	63	66	64	14.06^{a}	12.71^{ab}	11.67^{b}	10.71^{b}
2nd Cut	24/10/06	70^{a}	82^{ab}	87^{b}	94^{b}	7.20^{a}	5.94^{bc}	6.76^{ab}	5.23^{c}
3rd Cut	28/11/06	134	145	149	154	5.16^{a}	4.53^{b}	4.58^{ab}	5.37^{a}
4th Cut	2/1/07	177	174	181	181	1.84	1.78	1.65	1.73
5th Cut	6/2/07	233^{a}	193^{b}	212^{ab}	204^{b}	1.91^{b}	2.73^{a}	2.60^{a}	2.61^{a}
6th Cut	13/3/07	189	171	173	164	3.64^{d}	3.92^{c}	4.34^{b}	4.83^{a}
7th Cut	17/4/07	150^{a}	117^{b}	132^{ab}	129^{b}	4.15^{c}	5.38^{b}	5.29^{b}	6.26^{a}
8th Cut	22/5/07	139^{a}	113^{b}	111^{b}	114^{b}	3.86^{b}	5.39^{a}	5.67^{a}	5.81^{a}
9th Cut	26/6/07	105	104	104	108	7.69	8.21	7.57	7.48
10th Cut	31/7/07	127	127	129	143	4.30	3.95	3.85	3.90
11th Cut	4/9/07	138	136	140	151	3.99^{c}	4.93^{bc}	4.71^{bc}	5.93^{a}
Average	-	138	131	138	133	5.26	5.41	5.33	5.44

Means within a row followed by the different letter are different ($p<0.05$)
NS = Non significant difference ($p>0.05$) ** = Highly significant difference ($p<0.01$)

Table 4. There were no significant differences in NT and MTW (138, 131, 138 and 133 tillers/m^2; 5.26, 5.41, 5.33 and 5.44 g/tiller) among treatments. The current results are in agreement with Miyaki (1990) who found that NT and MTW were not significantly affected by cutting height. This behavior can be explained using the size-density compensation index, the least size of tillers is compensated by high tiller population density (Hernández *et al*., 1999).

In winter (during January to February, 2007) from the observation plant density in experimental plots found that the growth of grass was slow with the number of tillers increased but the size or weight of tillers was decreased. The leave size of grass was also small without new stems produced. This probably due to the grass may storage Total Non-structural Carbohydrate (TNC) in the stem during winter. Thus, a high TNC concentration may be beneficial to increase the tiller buds under a low temperature condition. TNC is considered as the source of energy for winter survival and regrowth after cutting (Kobayashi and Nishimura, 1978; Wadi *et al*., 2004). In addition, Jacques (1994) suggested that the largest number of vegetative tillers means greater numbers of leaves and consequently, greater numbers of buds for the development of axillary tillers.

However, it is known that some grasses have morphological and physiological and adaptations that allow bear repeated defoliation (Matches, 1992), hence the regrowth is dependent on the activation of the basal buds and the plant's ability to mobilize reserved carbohydrates from various parts (Caldwell *et al*., 1991).

Effect of cutting heights on pasture management: It is noted that management to fix the cutting height all year round is very hard to practice because after cutting the stubbles getting older which could lead to dying of grass. Hence, Tekletsadik *et al*. (2004) have suggested farmers refraining frequent cutting of their pasture in the dry season if they desire to produce maximum yield and get maximum benefit in the subsequent wet season. Tudsri *et al*. (2002) found 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 to April) is essential to improve dry season production and also reduce the effect of drought on subsequent pasture production. NRC (2001) recommends that milking cow weighting 450 kg giving 15 kg/day, should be fed at 2.8% DM of body weight and require 1,624 g CP/day. Thus, one cow fed 12.6 kg DM/day. If the ratio of roughage: concentrate is 60: 40. So, roughage for 1 cow is 7.56 kg/day or 2,760 kg/year. Hence, 1 ha of the King Napier grass pasture in 1 year can produces 71,403.1 kg and can feed 24 heads of milking cow throughout the year.

Conclusion: Based on this research, it can be concluded that the cutting height can affect the forage DM yield and nutritive values of King Napier grass. Cutting 35-day interval at 15 cm height above ground level could be the optimal level for harvesting King Napier grass in Northeast of Thailand. However, the experiments in second and third year crops still need to be clearly defined in order to provide practical recommendations to farmers especially those in the Northeast of Thailand.

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REFERENCES

AOAC, 1984. Official method of analysis. (14th) Association of Official Analytical Chemistry, Washington D.C., USA.

Aveiro, A.R., L. Siewerdt and A.P. Silviera Jr., 1991. Elephant grass: effects of irrigation and fertilization on mineral and organic. I. Content and total production of dry matter. Rev. Bras. Zootec., 20: 239-247.

Briske, D.D., 1986. Plant response to defoliation: morphological considerations and allocation priorities. In: Joss, P.J., Lynch, P.W., Williams, O.B. Eds. Rangelands: A resource under siege. Cambridge Univ. Press, pp: 425-427.

Caldwell, M., J.H. Richard and D.A. Johnson, 1991. Coping with herbivory: photosynthetic capacity and resource allocation in two Semiarid. Agrophyron bunchgrasses. Oecologia, 50: 14-24.

Caro-costor, R. and J. Vincente-Chandler, 1961. Cutting height strongly effects yields of tropical grasses. Agron. J., 53: 59-69.

Cook, B.G., B.C. Pengelly, S.D. Brown, J.L. Donnelly, D.A. Eagles, M.A. Franco, J. Hanson, B.F. Mullen, I.J. Partridge, M. Peters and R. Schultze-Kraft, 2005. Tropical Forages: an interactive selection tool, [CD-ROM], CSIRO, DPI&F(Qld), CIAT and ILRI, Brisbane, Australia. Available from: http//www.tropicalforages.info/key/Forages/Media/Html/*Pennisrtum purpuream*. Access on: Dec. 20, 2007.

Crowder, L.V. and H.R. Chheda, 1982. Tropical grassland husbandry. Longman Group Inc., New York: USA.

Duke, J.A., 1983. Handbook of energy crops. Available: *http://www.hort.purdue.edu/new crop/duke.energy/duke_ index.httm*. Accesses Oct. 10, 2003.

Ezenwa, I. and M.E. Aken'Ova, 1996. Effect of method of sowing Stylosanthes on forage production of a Panicum-Stylosanthes mixture. Trop. Grassld., 30: 363-366.

Goering, H.K. and P.J. Van Soest, 1970. Forage fiber analyses (apparatus, reagents, procedure and some applications). ARS, USDA. Washington D.C.

Gonçales, D.A., 1985. Elephant grass (*Pennisetum purpureum* Schum. cv. Roxo.) Botucatu. Bol. Ind. Anim., 42: 141-142.

Gonçalves C.A. and L.C. Coast, 1991. Organic manure, cut-off frequency of elephant grass (*Pennisetum purpureum* Schum, cv. Cameroon) in Porto Velho, Rondonia. Lav. Rice., 44: 27-29.

Hernández, G.A., C. Matthew and J. Hodgson, 1999. Tiller size-density compensation in perennial ryegrass miniature swards subject to differing defoliation heights and proposed productivity index. Grass and Forage Sci., 54: 347-356.

Humphreys, L.R., 1974. A Guide to Better pastures for the Tropics and Sub-tropics. 3rd Eds. Wright, Stephenson and Co. (Australia) Pty. Ltd., Victoria: Australia.

Jacques, A.V.A., 1994. Morphophysiological characters and their implications with the management. In: Carvalho M.M., Alvim, M.J. and Xavier, D.F. (Eds.). Elephant grass, production and use. Coronel Pacheco: not available. pp: 31-48.

JLTA, 1996. Technical manual for forage crops and grasslands in tropical and subtropical zone. Japan Livestock Technol. Assoc. (JLTA), pp: 412.

Kobayashi, T. and S. Nishimura, 1978. Winter hardiness and carbohydrate reserveof some tropical and subtropical grasses as affected by the final cutting date in autumn. J. Japan Grassl. Sci., 24: 27-33.

Matches, A.G., 1992. Plant response to grazing: A review. J. Prod. Agric., 5: 1-7.

Matthew, C., G. Lemaire, N. R.Sackville, A. Hamilton and G. Hernández, 1995. A modified self-thinning equation to describe size/density relationships for defoliated swards. Ann. Botany, 76: 579-587.

Milford, R. and D.J. Minson, 1966. In Tropical pastures. W. Davies and C.L. Skidmore, Ed. Faber and Feber, London.

Minson, D.J., 1981. Nutritional differences between tropical and temperate pastures. In Grazing animals. Morley F.H.W. editor. World animal science, series B; Elsevier North-Holland Inc.: The Netherlands.

Miyaki, E., 1990. Studies on productivity and feeding values of napier grass. 6). The effect of cutting height on the yield of napier grass. Sci. Bul. Coll. Aric. U. of the Ryukyus, 37: 203-214. (In Japanese and English Abstract).

Nakamanee, K., J. Khemsawet, T. Boonyawirote and W. Punpipat, 1996. Effect of cutting height and cutting interval on yield and chemical composition of 3 varieties of napier grass under irrigation. In Annual research report 1996. Animal Nutrition Division. Development of Livestock Department. Ministry of Agriculture and Cooperatives, Bankok, Thailand, pp: 123-128.

NRC, 2001. Nutrient requirements of dairy cattle. 7 Revised Edition, National Academy Press; Washington, D.C.

Ollerenshaw, J.H. and D.R. Hodgson, 1977. The effect of constant and varying height of cut on the yield of Italian ryegrass (*Lolium perenne* L.). J. Agric. Sci. Camb., 89: 425-434.

Orskov, E.R., 1982. Protein nutrition in ruminants. Academic Press. Inc. (London) Ltd. pp: 41-84.

Preston, T.R. and R.A. Leng, 1987. Matching ruminant production systems with available resources in the tropics and sub-tropic. Penambul books, Armidale; NSW: Aust.

Queiro Filho, J.L., D.S. Silva and I.S. Birth, 1998. Production of dry matter of quality of cultivars and varieties of elephant grass (*Pennisetum purpureum* Schum.). Rew. Bras. Zootec., 27: 262-66.

Santana, J.R., J.M. Pererira and N.G. Arruda, 1989. Evaluation of cultivars of elephant grass (*Pennisetum purpureum*, Schum.) in the south of Bahia. 1. Agrosystems cacao. Rew. Bras. Zootec., 18: 273-283.

Santos, C.J.A., 1994. Mineral composition, protein value and physiological factors of 4 varieties of elephant grass (*Pennisetum purpureum* Schum.) submitted to two age of cutting. Dissertation (M. in Animal Production), U. of Pernambuco, pp: 107.

Santos, E.A., D.S. da Silva and J. de Queiroz Filho, 2001a. Chemical composition of elephant grass cv. Roxo cut at different heights. Rev. bras. Zootec., 30: 18-23.

Santos, E.A., D.S. da Silva and J. de Queiroz Filho, 2001b. Productive aspects of elephant grass (*Pennisetum purpureum* Schum.) cv. Roxo in Balanga Paraibano. Rev. bras. Zootec., 30: 31-36.

SAS, 1998. SAS procedure Guide: Release 6.03 Ed. SAS Institute, Inc. Carly, North Calolina.

Silveira, A.C., H. Tosi and V.P. Faria, 1974. Effect of maturity on the chemical composition of the chemical Napier grass (*Pennisetum purpureum* Schum). Rev. Bras. Zootec., 3: 158-171.

Steel, R.G.D. and J.H. Torrie, 1960. Principles and procedures of Statistics. McGraw-Hill Book Company, Inc. New York, pp: 481.

Tekletsadik, T., S. Tusari, S. Juntakool and S. Prasanpanich, 2004. Effect of dry season cutting management on subsequent forage yield and quality of Ruzi *(Brachiaria ruziziensis)* and Dwarf napier (*Pennisetum purpureum*. L) in Thailand. Kastsart J. (Nat. Sci.), 38: 457-467.

Thinnakorn S., K. Pokesaward and S. Wittayanupapyeunyong, 1995. The production and persistency of 3 varieties of napier grass cut at different heights. In Annual research report. Animal Nutrition Division. Development of Livestock Department. Ministry of Agriculture and Cooperatives, Bankok, Thailand, pp: 185-196.

Trujillo, W., W.D. Pitman, C.D. Chambliss and K. Williams, 1996. Effect of height and frequency of cutting on yield, quality and persistence of *Desmanthus virgatus*. Trop. Grassld., 30: 367-373.

Tudsri, S., S.T. Jorgensen, P. Riddach and A. Poopakdi, 2002. Effect of cutting height and dry season closing date on yield and quality of five napier grass cultivars in Thailand. Trop. Grassld, 36: 248-252.

Wadi, A., Y. Ishii and S. Idota, 2004. Effect of cutting interval and cutting height on dry matter yield and overwintering ability at the established year in *Pennisetum* species. Plant prod. Sci., 7: 88-96.

Walton, P.D., 1984. Production and management of cultivated forages. Reston publishing Company. Inc. Virginia. USA., pp: 335.

Werner, J.C., F.P. Lima and D. Martinelli, 1966. Studies of three different cutting heights on elephant grass Napier. Bol. Ind. Anim., 23: 161-68.

Whiteman, P.C., 1980. Tropical pasture science. Oxford Univ. Press, New York.: USA., pp: 392.