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Forage growth, yield and quality responses of Napier hybrid grass cultivars to three cutting intervals in the Himalayan foothills

KESANG WANGCHUK[1], KRISHNA RAI[3], HARILAL NIROLA[2], THUKTEN[1], CHHOYTEN DENDUP[2] AND DURBA MONGAR[1]

[1]*Renewable Natural Resources Research and Development Center, Ministry of Agriculture and Forests, Bumthang, Bhutan.* www.moaf.gov.bt
[2]*Renewable Natural Resources Research and Development Center, Ministry of Agriculture and Forests, Yusipang, Bhutan.* www.moaf.gov.bt
[3]*National Jersey Breeding Center, Samtse, Bhutan*

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Abstract

A 3 x 3 factorial study was conducted in the southern foothills of Bhutan to compare 3 cultivars of Napier hybrid grass (*Pennisetum purpureum* x *P. glaucum*: Pakchong-1, CO-3 and Giant Napier), at 3 cutting intervals (40, 60 and 80 days), in terms of forage growth, dry matter (DM) yield and crude protein (CP) concentration. The effects of cultivar x cutting interval were significant only on tiller number per plant and leaf:stem ratio (LSR). CO-3 consistently produced the highest tiller number per plant, leaves per plant and LSR, while Pakchong-1 produced the lowest. Pakchong-1 plants were taller, had bigger tillers and basal circumference and higher stem DM production than CO-3 and Giant. Leaf CP for all cultivars was about 17%, while stem CP concentration was lower for Pakchong-1 than for the other cultivars (3.6 vs. 5.3%, P<0.05). While 40-day cutting intervals produced high quality forage, yields suffered markedly and the best compromise between yield and quality of forage seemed to occur with 60-day cutting intervals. Pakchong-1 seems to have no marked advantages over CO-3 and Giant for livestock feed, and feeding studies would verify this. Its higher stem DM yields may be advantageous for biogas production and this aspect should be investigated.

Resumen

En el piedemonte de la cordillera del Himalaya al sur de Bután en un factorial de 3 x 3 se compararon 3 cultivares (cvs.) híbridos del pasto Napier (*Pennisetum purpureum* x *P. glaucum*): Pakchong-1, Giant Napier y CO-3, en intervalos de corte cada 40, 60 y 80 días. Las mediciones incluyeron crecimiento del forraje, producción de materia seca (MS) y concentración de proteína cruda (PC). Los efectos de cultivar x intervalo de corte fueron significativos sólo para el número de brotes por planta y la relación hoja:tallo. El cv. CO-3 produjo de manera sostenida el mayor número tanto de brotes como de hojas por planta y la mayor relación hoja:tallo, mientras el cv. Pakchong-1 presentó respectivamente los valores más bajos. En comparación con los cvs. CO-3 y Giant, las plantas de Pakchong-1 fueron más altas, con brotes más vigorosos y circunferencia basal mayor, y produjeron más MS de tallo. La concentración de PC en las hojas fue aproximadamente de 17% para todos los cultivares, mientras que la concentración de PC en los tallos fue menor para Pakchong-1 que para los otros cultivares (3.6 vs. 5.3%, P<0.05). Cuando el intervalo de corte fue de 40 días, el forraje fue de mayor calidad, pero los rendimientos se redujeron marcadamente. Los resultados indican que con intervalos de corte de 60 días se obtiene el mejor compromiso entre el rendimiento y la calidad del forraje. Para la alimentación del ganado, el cv. Pakchong-1 no parece tener ventajas marcadas sobre los cvs. CO-3 y Giant; estudios de producción animal deberían verificar esto. Sin embargo, sus rendimientos particularmente altos de MS de tallo pueden ser favorables para la producción de biogás y este aspecto debe ser investigado.

Correspondence: Kesang Wangchuk, Renewable Natural Resources Research and Development Center, Ministry of Agriculture, Bumthang, Bhutan.
Email: kesangwangchuk@rocketmail.com

Introduction

The pasture species Napier or elephant grass (*Pennisetum purpureum*) is widely distributed in tropical and subtropical regions of the world, and is highly productive in areas with good soil fertility and high rainfall, growing well up to 2,000 masl (Kumar 2013). Napier grass is often preferred by smallholders and, e.g. in east Africa, constitutes up to 80% of forage grown (Staal et al. 1987). This has been attributed to its wide range of adaptation, vigorous growth, high biomass productivity and deep root system to survive under drought conditions (Lowe et al. 2003; Anderson et al. 2008; Tessema 2008).

However, optimal management practices for Napier grass are not clear (Mutegi et al. 2008). Appropriate cutting management is essential for high production and quality of this species (Jorgensen et al. 2010; Tessema et al. 2010). Since the species is well suited for cut-and-carry systems (Bayer 1990), many studies have dealt with cutting management to optimize forage yield and quality of Napier grass (Bayble et al. 2007; Tessema et al. 2010; Rengsirikul et al. 2011). While Manyawu et al. (2003) reported a significant effect of growth stage on yield and quality and suggested a cutting interval of 6−7 weeks for optimum yield and quality of Napier grass, Tessema et al. (2010) obtained the highest crude protein (CP) concentration at about 13 weeks cutting interval. Ansah et al. (2010) recorded the highest CP concentration but lowest DM yield, when harvested at less than 9 weeks cutting interval.

These findings highlight the importance of optimum cutting interval and its varying effects on yield and quality. High cutting frequency reduces growth and development, whereas long intervals between harvests lead to accumulation of fiber and reduction in quality (Tessema et al. 2010). This is because Napier grass has high structural cell wall carbohydrates that increase rapidly with maturity causing decline in CP concentration and digestibility (Van Soest 1994). Studies also demonstrate that the effects of cutting interval on yield and quality vary with cultivars (Cuomo et al. 1996; Khairani et al. 2013), management practices and environmental conditions (Chaparro et al. 1996). Genotypic variation in growth characteristics of Napier grass has also been reported (Mwendia et al. 2006; Nyambati et al. 2010) and growth and morphological characteristics are correlated with DM yield and nutritional quality (Tudsri et al. 2002).

In the southern foothills of the Bhutan Himalaya, Napier grass is a promising and high-yielding fodder species, widely cultivated in smallholder systems and on commercial livestock farms. However, the number of cultivars in the field is limited and existing cultivars include Mott (dwarf type) and the hybrids CO-3 and Giant Napier. Recently, the hybrid cultivar Pakchong-1 was introduced from Thailand. Under good management, Pakchong-1 is known for fast growth with high forage yield, high CP concentration (16−18%) and wide range of adaption, and can be ratooned for up to 8 years (Kiyothong 2014). These features seem to compel the Department of Livestock to promote and encourage large scale multiplication of Pakchong-1 in the southern foothills. However, forage crops are highly area, location and season-specific (Tessema et al. 2010; Pandey and Roy 2011) and there is a need to verify if Pakchong-1 can outcompete the existing cultivars in terms of forage yield, quality and growth characteristics, under the wet subtropical conditions of the southern foothills. Therefore, the main objective of this study was to compare hybrid Napier grass cv. Pakchong-1 with cvv. CO-3 and Giant at 3 cutting intervals, in terms of forage growth characteristics, DM yield and quality. The cutting intervals were chosen in an attempt to identify the interval which might optimize forage yield and quality of these cultivars.

Materials and Methods

Study site

The field experiment was conducted from August 2013 to November 2014 at the National Jersey Breeding Center of Samtse district (27°02′ N, 89°05′ E; 260 masl) in southern Bhutan. The center has a total area of 124 ha and about 50% of the land is planted with improved subtropical pasture species (Ministry of Agriculture 2000). Topography is rugged. The mean maximum temperature of 35 °C is recorded in July and the mean minimum of 15 °C in January. Average annual rainfall is 900 mm and shows a unimodal distribution pattern, with the main precipitation from June to September, giving hot, wet summers and cold, dry winters. The growing season occurs between April and November. Rainfall recorded during the study period is presented in Figure 1.

Soil nutrient analysis

Soil is sandy loam with poor moisture holding capacity (Ministry of Agriculture 2000) and pastures are fertilized with effluents from the dairy sheds. Soils were sampled to a depth of 15 cm by collecting 10 samples of 300 g from the field prior to commencement of the experiment.

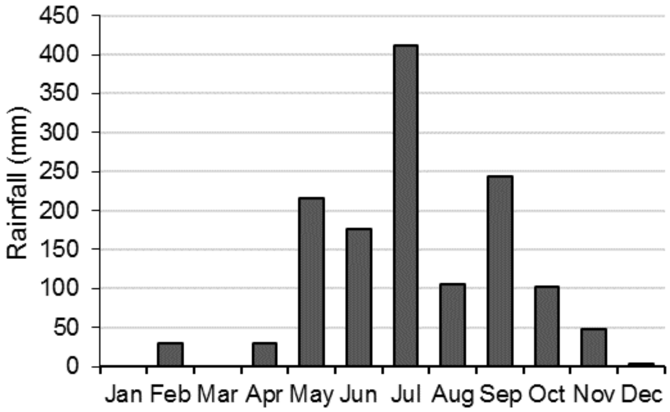

Figure 1. Monthly rainfall at study site in 2014.

The soil samples were dried at ambient temperature and analyzed at the National Soil Services Center at Semtokha, Bhutan. The methods used were micro-Kjeldahl digestion (Guebel et al. 1991) for total nitrogen (N), Bray and Kurtz method (Bray and Kurtz 1945) for available phosphorus (P) and the semi-micro leaching method (Blakemore et al. 1981) for exchangeable potassium (K^+). The laboratory results showed the following chemical composition: available P 133 mg/kg; available K 37.8 mg/kg; carbon 3.42%; nitrogen 0.22%; and C:N ratio 16.0.

Description of cultivars

Hybrid Napier grass cvv. Pakchong-1, CO-3 and Giant were used in this study. All 3 cultivars are derived from interspecific crosses between common elephant grass (*Pennisetum purpureum*) and pearl millet (*Pennisetum glaucum*).

Hybrid Napier cv. Pakchong-1 was developed by the Department of Livestock Development in Thailand. It is reported to grow over 3 m tall in less than 2 months, gives high yields and can be harvested after 45 days with a CP concentration of 16−18% (Kiyothong 2014).

Hybrid Napier cv. CO-3 was developed by the Tamil Nadu Agricultural University at Coimbatore, India and released for commercial cultivation in 1997 (Premaratne and Premalal 2006). It is characterized by profuse tillering, high yield potential, high CP concentration, quick regrowth capacity, high leaf:stem ratio, high palatability and freedom from pests and diseases (Premaratne and Premalal 2006).

Giant Napier was developed by the Indian Agricultural Research Institute (Patil and Joshi 1962). It is a robust plant with a vigorous root system, sometimes stoloniferous and with a creeping rhizome. It gives high yield especially under adequate fertilization and irrigation, but has high fiber content at maturity and poor seed production and is susceptible to frosts (Patil and Joshi 1962).

Experimental design and treatments

The study was established in August 2013. A 3 x 3 factorial experiment (3 cultivars − Napier grass cvv. Pakchong-1, CO-3 and Giant Napier grass x 3 cutting intervals – 40, 60 and 80 days) was laid out in 3 blocks (3 replications). Plot size for each cultivar was 25 m^2 (5 × 5 m). Twenty-five stem cuttings per cultivar per plot with 2 healthy nodes per cutting were planted on 8 August 2013 with a 1 x 1 m spacing. Plants along the borders of plots were excluded from measurement and were cut and forage disposed of at the time of field measurements. Only 10 plants per cultivar were sampled at each cutting interval. After each cut, cow dung slurry (prepared by mixing 0.2 kg fresh cow dung in 1 L water) was applied uniformly at the rate of 1 L/m^2. No chemical fertilizers were applied. Weeds were slashed at the time of cutting.

Measurement of morphological characteristics

Napier plants were allowed to establish well in 2013 and field measurements were carried out in 2014. Plants of all treatments were uniformly cut to a standard height of 5 cm on 20 March 2014. Harvest dates for the cutting treatments are presented in Table 1.

At the time of harvest, each plant constituted a bunch of tillers. Plant height, basal circumference at 10 cm above ground level and number of tillers per plant were recorded. The tallest tiller on each plant was used to measure height, tiller diameter and number of leaves per tiller. Diameter of the lowest node was measured with digital Vernier calipers. Total number of leaves was estimated from the tiller number per plant and leaf number per tiller.

Table 1. Harvest dates for cutting treatments in 2014.

Cutting interval	Harvest dates in 2014	Number of cuts
40 days	30 Apr, 10 Jun, 20 Jul, 30 Aug, 10 Oct, 20 Nov	6
60 days	20 May, 20 Jul, 20 Sep, 20 Nov	4
80 days	10 Jun, 30 Aug, 20 Nov	3

Forage dry matter (DM) production, leaf:stem ratio (LSR) and crude protein (CP) concentration

Individual plants were clipped at 5 cm from ground level and fresh stems and leaves of each of the 10 harvested plants were separated and weighed. After individual plant measurements, stems and leaves were bulked separately and subsamples (about 300 g for stems and leaves) taken for DM analysis. The subsamples were oven-dried at 60 °C for 48 h and leaf and stem DM % determined. On the basis of these DM % and fresh stem and leaf yields we estimated the stem and leaf DM yield of each plant. Leaf dry weight was divided by stem dry weight to estimate the leaf:stem ratio (LSR). Following DM estimation, the dried samples were processed and analyzed for total nitrogen (N) by the Kjeldahl method and CP was estimated as % N × 4.43. The conversion factor 6.25 was not used because we felt it would overestimate the plant protein concentration, and instead we used 4.43, a conversion factor reported to provide reasonably good estimates of the plant protein concentration (Yeoh and Wee 1994).

Data analysis

Data for the various harvests for each plot were averaged. The dataset was checked for outliers, followed by Shapiro Wilk's and Levene's tests for normality of data and homogeneity of variance, respectively. Pearson's correlation was run to find relationships between growth parameters. The Generalized Linear Model with a 2-factor ANOVA was used to compare the mean differences between cultivars subjected to the 3 cutting intervals. Measured variables with cutting dates were treated as response variables and cultivar as the explanatory variable. Tukey's LSD test was used to test the differences between means. Differences between means were considered significant if P values were less than 0.05. We analyzed the dataset in SPSS version 21 (Landau and Everitt 2004).

Results

Growth characteristics

The effects of cultivar and cutting interval on plant height, basal circumference, tiller number and diameter and leaf number are presented in Table 2. The only significant interaction between cultivar and cutting interval was for number of tillers per plant, so main effects only are presented. For cultivars, plant height followed the order Pakchong-1>Giant>CO-3, while basal circumference and tiller diameter for Pakchong-1 and Giant were similar and greater than for CO-3 ($P<0.05$). Cutting interval had significant effects on plant height and basal circumference, with height increasing progressively as cutting interval increased ($P<0.05$), while basal circumference at 60 and 80 day cutting exceeded that at 40 day cutting ($P<0.05$). Cultivar had a significant effect on number of leaves/tiller (Pakchong-1>CO-3, $P<0.05$) and leaves/plant (CO-3>Giant and Pakchong-1, $P<0.05$). Cutting interval had a significant ($P<0.05$) effect on leaves/plant (40 and 60>80 days).

There was a significant cultivar x cutting interval effect on the number of tillers per plant. While the number of tillers declined significantly for all cultivars with increasing cutting intervals, at all cutting intervals CO-3 gave the highest number of tillers and Pakchong-1 gave the least.

Table 2. Effects of cultivar and cutting interval on plant height, basal circumference, tiller number and diameter, and leaf numbers of 3 Napier hybrid cultivars. Means ± standard error followed by the same letter within columns are not different ($P>0.05$).

Treatment	Plant height (cm)	Basal circumference (cm)	Tillers per plant (no.)	Tiller diameter (mm)	Leaves per tiller (no.)	Leaves per plant (no.)
Cultivar						
CO-3	175 ± 5.6 c	110.0 ± 3.3 b	72.0 ± 3.2 a	4.0 ± 1.70 b	5.0 ± 0.8 b	360 ± 4.0 a
Giant	206 ± 5.6 b	141.0 ± 3.3 a	51.0 ± 3.3 b	13.8 ± 2.62 a	6.0 ± 0.6 ab	306 ± 3.6 b
Pakchong-1	244 ± 5.4 a	142.0 ± 3.2 a	40.0 ± 3.1 c	13.1 ± 2.52 a	7.0 ± 0.5 a	280 ± 3.5 b
Cutting interval						
40 days	151 ± 4.5 c	119.0 ± 2.7 b	63.0 ± 2.6 a	13.5 ± 2.45 a	6.0 ± 0.4 a	378 ± 2.4 a
60 days	218 ± 5.4 b	137.0 ± 3.2 a	57.0 ± 3.1 b	10.9 ± 2.27 a	7.0 ± 0.5 a	399 ± 3.5 a
80 days	256 ± 6.4 a	137.0 ± 3.8 a	43.0 ± 3.7 c	11.8 ± 3.21 a	6.0 ± 0.6 a	258 ± 3.6 b

Table 3. Effects of cultivar and cutting interval on leaf and stem DM production and leaf:stem ratio (LSR) of 3 Napier hybrid cultivars. Means ± standard error followed by the same letter within columns are not different (P>0.05).

Treatment	Leaf DM (kg/plant)	Stem DM (kg/plant)	Total DM (kg/plant)	LSR
Cultivar				
CO-3	0.33 ± 0.0 a	0.23 ± 0.0 b	0.56 ± 0.0 b	1.43 ± 0.2 a
Giant	0.34 ± 0.0 a	0.27 ± 0.0 ab	0.61 ± 0.0 a	1.26 ± 0.2 b
Pakchong-1	0.31 ± 0.0 a	0.33 ± 0.0 a	0.64 ± 0.0 a	0.94 ± 0.2 b
Cutting interval				
40 days	0.2 ± 0.0 b	0.04 ± 0.0 c	0.24 ± 0.0 c	5.00 ± 0.1 a
60 days	0.4 ± 0.0 a	0.35 ± 0.0 b	0.75 ± 0.0 b	1.14 ± 0.2 b
80 days	0.4 ± 0.0 a	0.43 ± 0.0 a	0.83 ± 0.0 a	0.93 ± 0.2 b

Forage DM production and LSR

The effects of cultivar and cutting interval on leaf and stem DM production and LSR are presented in Table 3. The only parameter for which there was a significant cultivar x cutting interval effect was LSR. LSR at 40 days cutting interval was greater for Giant and Pakchong-1 but declined sharply as the cutting intervals increased with the greatest effect for Pakchong-1 (P<0.05). The mean LSR values for Giant Napier were 4.50, 1.25 and 1.00 for 40, 60 and 80 days cutting intervals, respectively. Pakchong-1 gave mean LSR values of 4.80, 0.82 and 0.67 for 40, 60 and 80 days, respectively, while corresponding values for CO-3 were 3.75, 1.52 and 1.20.

Amongst the main effects, cultivar had a significant effect on stem DM production (Pakchong-1>CO-3, P<0.05) whereas cutting interval had a significant (P<0.05) effect on leaf DM/plant (60 and 80>40 days) and stem DM/plant (80>60>40 days).

Protein concentration

Cultivar had a significant effect on stem CP concentration with CO-3 and Giant exceeding Pakchong-1 (P<0.05) (Table 4). CP concentration of leaves declined dramatically with increase in cutting interval from 28.2% at 40 days to 8.8% at 80 days (P<0.05). Similarly CP concentration in whole plants declined from 40 to 80 days (P<0.05).

Correlation between growth parameters

As complementary information, correlations between growth parameters are presented in Table 5. While basal circumference was positively correlated with plant height, tiller number, leaf number and stem DM, plant height was positively correlated with leaf number and stem DM but negatively correlated with tiller number per plant. On the other hand, tiller number was negatively correlated with tiller diameter and stem DM but positively correlated with leaf number. Leaf DM was strongly and positively correlated with leaf:stem ratio.

Table 4. Effects of cultivar and cutting interval on CP concentration (% N x 4.43) of leaf and stem of 3 Napier hybrid cultivars. Means ± standard error followed by the same letter within columns are not different (P>0.05).

Treatment	Leaf	Stem	Whole plant (calculated)
Cultivar			
CO-3	16.5 ± 0.30 a	5.1 ± 0.35 a	10.8 ± 0.32 a
Giant	16.8 ± 0.30 a	5.6 ± 0.35 a	11.2 ± 0.32 a
Pakchong-1	17.2 ± 0.30 a	3.6 ± 0.35 b	10.4 ± 0.32 a
Cutting interval			
40 days	28.2 ± 0.32 a	-	28.2 ± 0.32 a
60 days	13.8 ± 0.26 b	5.2 ± 0.32 a	9.5 ± 0.29 b
80 days	8.8 ± 0.26 c	4.3 ± 0.26 a	6.6 ± 0.24 c

Table 5. Correlations between growth and production parameters of Napier grass.

Growth parameter	Basal circumference	Plant height	Tillers per plant	Tiller diameter	Leaves per plant	Leaf DM	Stem DM
Plant height (cm)	0.38**						
Tillers per plant (no.)	0.16*	-0.54**					
Tiller diameter (mm)	0.15	0.15	-0.32**				
Leaves per plant (no.)	0.34**	0.83***	0.75***	0.14			
DM leaf (kg/plant)	-0.03	-0.08	0.08	0.01	0.08		
DM stem (kg/plant)	0.44**	0.79***	-0.33***	0.01	0.07	-0.02	
LSR	-0.05	-0.11	0.09	-0.06	-0.09	0.99***	-0.05

Discussion

Growth characteristics of the 3 Napier grass cultivars responded to the varying defoliation regimes, demonstrating that defoliation impacts the morphological development and forage quality of Napier grass (Manyawu et al. 2003; Tessema 2005; Halim et al. 2013). The significantly taller plants, bigger tillers, bigger basal circumference and higher stem DM in Pakchong-1 highlight the vigorous growth of this cultivar and its adaptation to the wet subtropical conditions in the southern foothills of Bhutan. The bigger basal circumference and higher stem DM yield also suggest lower planting densities should be employed for this cultivar. Giant Napier appeared similar to Pakchong-1 in most morphological traits except for plant height.

The significant decline in tiller number with increasing cutting intervals for all 3 cultivars conforms with the reports of other studies that tillering is enhanced under frequent cutting (Clavero 1997; Onyeonagu and Asiegbu 2012). Zhang and Romo (1995) and Jones and Mott (1980) highlighted the need to focus on tillering and understanding tiller dynamics, when assessing the effects of different management strategies on population dynamics. Increased tillering is probably an adaptive feature to tolerate frequent defoliation by re-establishing lost photosynthetic area and maintaining basal area. Jones (1985) attributed increased tiller production to removal of apical dominance by defoliation and activation of basal buds, while low tiller production under long cutting intervals has been linked to higher mortality of tillers under reduced cutting frequency (Clavero 1997). Regardless of cutting regime CO-3 consistently produced the highest number of tillers, which demonstrates the profuse tillering capacity of this cultivar (Premaratne and Premalal 2006). High tiller production not only indicates stable productivity (Mukhtar 2006) but also is linked to better persistence after periods of unfavorable environmental conditions (Assuero and Tognetti 2010). Lafarge and Loiseau (2002) consider tiller production is a key factor in the resistance of grasslands to deterioration by ageing. Pakchong-1 consistently produced fewer but larger tillers.

While CO-3 had fewest leaves per tiller, its greater tillering ability resulted in more leaves per plant, which is a desirable attribute when producing forage for livestock. Despite this advantage, total leaf DM in all cultivars was similar. The leaf fraction determines pasture quality (Davison et al. 1981) and performance of animals is related to the amount of leaf in the diet (Tudsri et al. 2002).

The decrease in LSR with increase in cutting interval agrees with the reports of Smart et al. (2004) and Tessema et al. (2010) that LSR decreases with decrease in defoliation frequency. Decrease in LSR with longer cutting intervals is a function of the longer periods of physiological growth with reduced defoliation frequency stimulating stem growth at the expense of leaf production (Butt et al. 1993). Except when cut frequently, CO-3 produced the highest LSR, which is an important beneficial trait of this cultivar. CO-3 was the shortest among the cultivars tested and dwarf cultivars have been reported to produce a higher LSR over a wide range of maturities (Sukkagate et al. 1997), which is reflected in higher overall nutritive quality compared with taller varieties (Halim et al. 2013). Dwarf varieties also have higher tiller number, leaf area index and percentage of leaf than the normal and tall varieties of Napier grass. This result is of significance from the forage standpoint since LSR is an important factor affecting diet selection, quality and intake of forage (Smart et al. 2004). Since leaf DM yields of all cultivars were similar, it was the higher stem DM yields in Pakchong-1 and Giant that resulted in the lower LSR in these cultivars.

Leaf material for all 3 cultivars was of high quality with CP concentrations about 17%. While stems of all cultivars had lower CP concentrations than leaf, the mean values for total forage were still above the 1% N suggested by Milford and Minson (1966) as the figure below which feed intake is restricted.

In conformity with the report of Tessema et al. (2010), we found that a short cutting interval of 40 days seriously reduced DM yields of all cultivars. While protein concentration was very high, this would scarcely compensate for the greatly reduced forage production. On the contrary, except for Pakchong-1, a long interval of 80 days resulted in taller plants susceptible to lodging during strong winds. A general decline in CP concentration with increasing cutting interval corresponds with the results of other studies showing decline in CP with advancing phenological stages (Manyawu et al. 2003; Khaled et al. 2005; Peiretti et al. 2015). We consider that an intermediate cutting interval of 60 days appears optimal for the subtropical conditions of Bhutan. This is supported by our results revealing high leaf DM production, and acceptable CP concentration and LSR at 60 days cutting interval. Ansah et al. (2010) obtained the highest CP concentration when Napier grass was harvested at less than 9 weeks cutting interval but DM yields were low, while Van Man and Wiktorsson (2003) achieved the best balance between DM yield and forage quality of Napier grass at 8 weeks cutting interval.

It seems that Pakchong-1 is not superior to Giant Napier and CO-3, which is at variance with the higher CP concentration of 16−18% for Pakchong-1 reported from Thailand (Kiyothong 2014). There are two possible explanations for the contrast in results between southern Bhutan and Thailand. Firstly, the study site had only moderate levels of soil N, which may have affected CP concentration, since CP in forages is positively correlated with soil N (Mohammad et al. 1988; Singh et al. 2000). Secondly, climatic conditions differ greatly between the 2 countries. Thailand experiences a hot, humid tropical climate for most of the year, while the climate of the southern foothills of Bhutan is hot and humid in summer but cold and dry in winter. While Pakchong-1 might be ideally suited to a tropical climate, e.g. in Thailand, it may not perform to its full potential in the southern foothills of Bhutan.

Conclusion

While all 3 Napier hybrid grass cultivars performed well in the southern foothills of Bhutan, they varied in terms of growth characteristics, forage yield and quality. Cultivar CO-3 was superior to Pakchong-1 and Giant Napier in terms of leafiness and tiller production but Pakchong-1 had faster growth rate, bigger tillers and higher overall DM production. While Kiyothong (2014) suggested cutting as often as every 45 days to produce material of 16-18% CP, DM yields would suffer markedly under such a regime. From the forage standpoint under the environmental conditions of the southern foothills of Bhutan, Pakchong-1 Napier appears to have no real advantages over CO-3 and Giant Napier. However, there might be situations where attributes of Pakchong-1 could be beneficial for dairy farmers.

Pakchong-1's fast regrowth and high DM yield might be advantageous in conserving soil and providing early fodder. In the southern foothills, biogas production is practiced to meet energy needs of rural households. Under this scenario, the high DM yield and high stem production of Pakchong-1 could be important attributes for methane gas production. This aspect should be investigated.

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