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Effect of nitrogen on yield and quality of *Panicum maximum* cvv. Mombasa and Tanzania in Northeast Thailand

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Abstract

A field trial in Northeast Thailand during 2011–2012 compared the effects of nitrogen fertilizer, applied as urea in the wet season, on the growth and quality of *Panicum maximum* cvv. Mombasa and Tanzania. In the establishment year, increasing rates of nitrogen (0, 20, 40 and 60 kg N/ha every 40–45 days) (0–180 kg N/ha for growing period) progressively increased stem, leaf and total DM production (P<0.05). At higher rates (80 and 100 kg N/ha or 240–300 kg N/ha for growing period), only total DM increased at the highest rate. In the second year, a rate of 20 kg N/ha every 40–45 days (80 kg N/ha for growing season) doubled the amount of DM compared with no nitrogen, and 80 kg N/ha every 40–45 days (320 kg N/ha for growing period) produced significantly higher stem, leaf and total DM yields than most other rates. The yield response (kg DM/kg N) decreased linearly (24.7 to 20.3 in 2011; 56.7 to 15.1 in 2012) from the lowest to the highest rate of nitrogen. In both years, increasing rates of nitrogen significantly increased CP and NDF concentrations in stems and leaves and ADF concentrations in stems. Mombasa produced 17 and 19% more leaf and 18 and 22% more total DM than Tanzania, in the first and the second year, respectively. Mombasa also produced 30% more stem DM than Tanzania in the second year. While Tanzania produced higher CP levels than Mombasa in the establishment year, in the second year, Tanzania had higher levels than Mombasa only when N rates of 80–100 kg N/ha were applied every 40–45 days (320–400 kg N/ha for growing period). Applying 60 kg N/ha every 40–45 days appears to be a reasonable compromise to achieve satisfactory DM yields in the wet season (8,000 kg/ha first year and 12,000 kg/ha second year), leaf percentage of 68–70% and leaf CP concentrations above 7%.

Resumen

En el noreste de Tailandia durante 2011−2012 se compararon bajo condiciones de campo los efectos de la fertilización con nitrógeno, aplicado en forma de urea en época de lluvias, en el crecimiento y la calidad de los cultivares Mombasa y Tanzania de *Panicum maximum*. En el año de establecimiento, el incremento de los niveles de nitrógeno (0, 20, 40 y 60 kg/ha, aplicados cada 40−45 días, o sea 0−180 kg N/ha para el período de crecimiento) aumentó proporcionalmente la producción de materia seca (MS) de tallos y hojas, así como la MS total (P<0.05). En los 2 niveles más altos (80 y 100 kg/ha o 240−300 kg N/ha para el período de crecimiento), sólo la producción de MS total mostró respuesta significativa y sólo al nivel más alto de N. En el segundo año, la fertilización con 20 kg N/ha cada 40−45 días (80 kg N/ha para el período de crecimiento) duplicó la producción de MS en comparación con el testigo (0 kg N/ha), y la aplicación de 80 kg N/ha cada 40−45 días (320 kg N/ha para el período de crecimiento) permitió obtener producciones de MS de tallos, hojas y MS total significativamente mayores que los de demás niveles de N aplicados. La respuesta de la producción a la fertilización (kg MS/kg N) disminuyó linealmente (de 24.7 a 20.3 en 2011, y de 56.7 a 15.1 en 2012) desde el más bajo hasta el más alto nivel de N aplicado. En ambos años, el incremento de los niveles de N aumentó

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significativamente las concentraciones de proteína cruda (PC) y fibra detergente neutro en tallos y hojas y las concentraciones de fibra detergente ácido en tallos. El cv. Mombasa produjo 17 y 19% más MS de hojas y 18 y 22% más MS total que Tanzania, en el primero y el segundo año, respectivamente. Mombasa también produjo 30% más MS de tallos que Tanzania en el segundo año. Mientras en el año de establecimiento las concentraciones de PC fueron en todos los niveles de N más altas en Tanzania que en Mombasa, en el segundo año Tanzania presentó concentraciones superiores que Mombasa solamente cuando las dosis de N de 80−100 kg N/ha fueron aplicadas cada 40−45 días (320−400 kg N/ha para el período de crecimiento). La aplicación de 60 kg N/ha cada 40−45 días aparentemente resulta razonable para obtener en la época de lluvias producciones de MS satisfactorias (8 t/ha el primer año y 12 t/ha el segundo), con 68−70% de hojas y concentraciones de PC en las hojas mayores que 7%.

Introduction

Pastures in Northeast Thailand are usually grown on the poorest soils, as more fertile soils are used for growing food and cash crops. Many improved pastures in the region are nitrogen-deficient, as village farmers usually apply a maximum of only 20–40 kg N/ha in the 6-month wet season, if they apply any fertilizer at all. The exceptions are the larger commercial dairy farms (about 1,000 larger farms, milking on average 100 cows with an average size of 20 ha) and small village farmers, who grow guinea grass for sale as fresh forage. In both of these systems, fertilizer is applied at rates of 10–20 kg N/ha 3–6 times in a wet season or when irrigated in the dry season (Udchachon et al. 1998; Nakamanee et al. 2008).

Tanzania guinea grass [*Panicum maximum* − now *Megathyrsus maximus* − cv. Tanzania (cv. Si Muang in Thailand)] is the most commonly grown grass in Thailand (Khemsawat and Phaikaew 2007; Phaikaew et al. 2007). In a 3-year field trial in Northeast Thailand, Tanzania guinea grass produced dry matter (DM) yields of 10 and 11 t/ha in successive 6-month wet seasons, when fertilized with 200 kg NPK/ha (15:15:15) every 40–45 days, a total of 120 kg N/ha (Hare et al. 2009). Under intensive cutting every 30–40 days for the sale of fresh forage in Northeast Thailand, Tanzania guinea grass produced DM yields of 33–46 t/ha/yr (Nakamanee et al. 2008). In this system, farmers applied 125–310 kg urea/ha (46% N) or 160–310 kg NPK/ha (16:7:6) after each cut, a total of approximately 500–1,000 kg N/ha/yr. In addition, poultry manure at a rate of 2.8–5.6 t/ha was applied every 60–90 days.

Mombasa guinea grass (*Panicum maximum* – now *Megathyrsus maximus* – cv. Mombasa) was introduced to Thailand 7 years ago from Brazil (Hare et al. 2013). Since there were no data on growth of Mombasa in Thailand, a series of studies has been undertaken at Ubon Ratchathani University, Thailand, to study the botanical and agronomic differences between Mombasa and Tanzania. The first of these studies found that, under cutting, Mombasa produced 17–21% more total DM and 18–24% more leaf DM than Tanzania (Hare et al. 2013). The second of these studies, examining varying seeding rates, found that Mombasa produced 23% more DM than Tanzania in successive wet seasons (Hare et al. 2014). In both studies, 200 kg NPK/ha (15:15:15) was applied every 45–50 days, a total of 120 kg N/ha/yr in the first study and 180 kg N/ha/yr in the second study.

This paper, which examines the effects of rates of nitrogen (N), deals with the third of these studies. The objective was to examine the production and quality of Mombasa and Tanzania guinea grasses under different levels of N fertilizer, in order to recommend an optimum N rate for these grasses growing on poor sandy soils in Northeast Thailand.

Materials and Methods

This study was conducted at a site at the Amnart Charoen Livestock Development Centre, Amnart Charoen province, Northeast Thailand (15.5° N, 104.4° E; elevation 130 masl) during 2011–2012. The site was on an upland sandy reddish brown earth (Haplustalf) soil (Chatturat series) (Mitsuchi et al. 1986). Soil samples taken at sowing in June 2011 showed that the soil was acid (pH 4.8; water method), very sandy (75% sand) and low in organic matter (0.6%), N (0.03%) and K (42 ppm) and average for P (24.3 ppm; Bray II extraction method). Prior to cultivation, the site had been planted with hybrid brachiaria lines for 3 years. The grasses were sprayed with glyphosate (3 L/ha) in May 2011, plowed and disked before the guinea grass seeds were sown on 16 June 2011.

Two guinea grass cultivars (Mombasa and Tanzania) were sown at 6 kg seed/ha in a randomized complete block design with 4 replications. The treatments were 2 cultivars x 6 nitrogen rates (0, 20, 40, 60, 80 and 100 kg N/ha) applied as urea (46% N) every 40–45 days. The seeds were hand-broadcast on to the seed beds and the seed lightly surface-raked into the soil. At sowing, lime (1,000 kg/ha), double superphosphate at 100 kg/ha (19.8 kg P/ha) and potassium chloride at 100 kg/ha (49.8 kg K/ha) were applied. Plots measured 4 x 3 m.

All plots were cut to 5 cm above ground level on 19 July 2011 and the N treatments commenced. Nitrogen was applied again after each sampling, except at the final cut, when the trial ceased over the dry season. In the first year (2011), N was applied 3 times (19 July, 1 September and 13 October) for totals of 0, 60, 120, 180, 240 and 300 kg N/ha for the various treatments. In the second year (2012), N was applied 4 times (25 April, 7 June, 23 July and 6 September) for totals of 0, 80, 160, 240, 320 and 400 kg N/ha.

Forage sampling, from six 0.25 m^2 quadrats per plot, was carried out in the first year, on 1 September, 13 October and 30 November 2011. After the November sampling, all plots were cut to 5 cm above ground level and not cut again until April 2012, when the fertilizer applications recommenced on the same plots. Forage sampling then occurred on 7 June, 23 July, 6 September, and 24 October 2012.

At each sampling, the fresh samples from the 6 quadrats were combined and weighed and a 300 g subsample from each plot was hand-sorted into leaves and stems and dried at 70 °C for 48 h to calculate DM of stems and leaves and total DM. Samples from the dried material were analyzed for total N (Kjeldahl method) in order to calculate crude protein (%N x 6.25), acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations. After each sampling, the remaining forage in the plots was cut to 5 cm above ground level before applying fertilizer.

Data from the trial were subjected to analysis of variance, using the IRRISTAT program from the International Rice Research Institute (IRRI). Entry means were compared by LSD at P=0.05 probability level.

Results

Rainfall

Rainfall from sowing in June 2011 until November 2011 was 25% higher than the 12-yr mean for the same period (Figure 1), with particularly heavy rainfall in August 2011. In the second year, rainfall from April to October 2012 was 27% lower than the 12-yr mean.

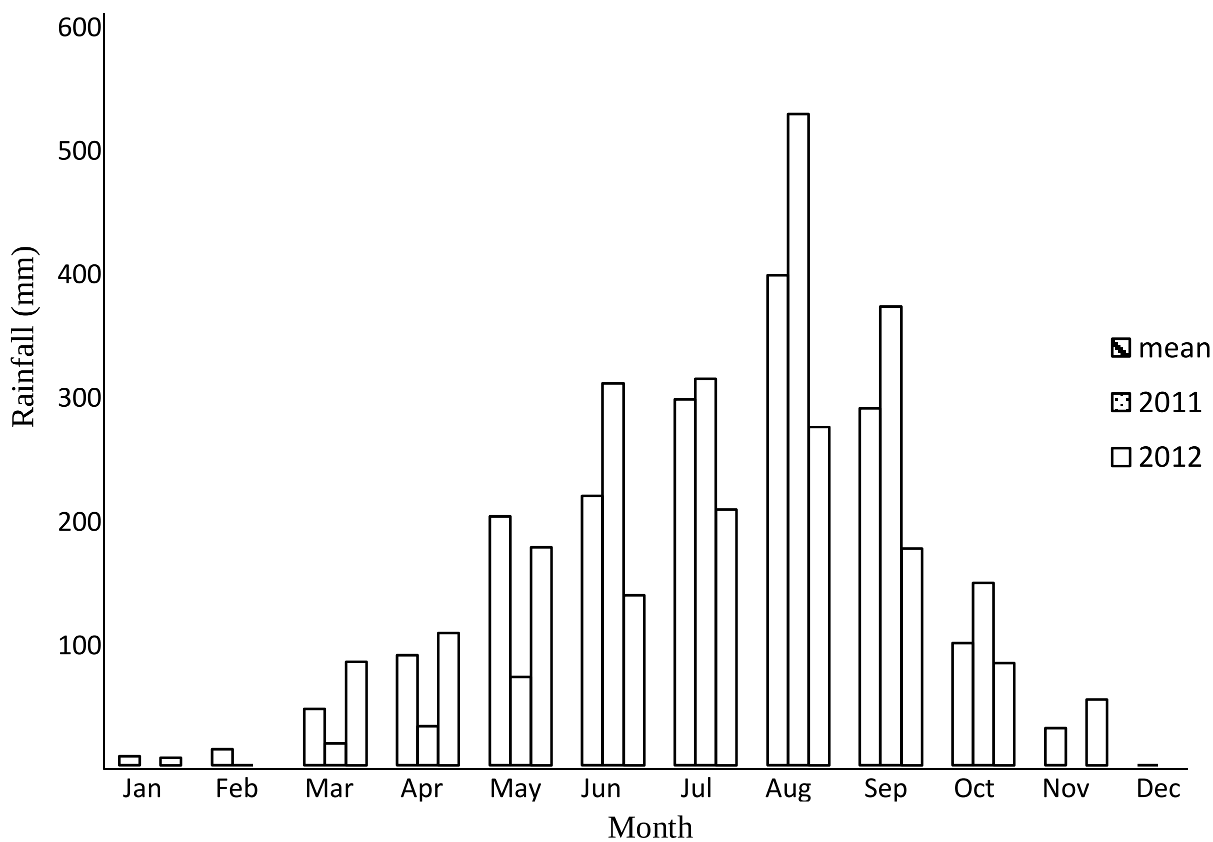

Figure 1. Rainfall during the trial at the Amnart Charoen meteorological station, 9 km from the research site, and the 12-yr mean (2000–2012).

Dry matter production and quality

In the establishment year, increasing rates of fertilizer up to a rate of 60 kg N/ha, progressively increased stem, leaf and total DM production (P<0.05). At higher N rates, increases in production were slight and significant for total DM at 100 kg/ha only (Table 1). In the second year, while a rate of 20 kg N/ha almost doubled the amount of DM compared with unfertilized plots, yield increases occurred up to 80 kg N/ha and then declined when 100 kg N/ha was applied (Table 2). A rate of 80 kg N/ha produced significantly higher stem, leaf and total DM yields than all other rates except 60 kg N/ha (Table 2). In both years, the percentage of leaf in the forage was significantly reduced when nitrogen was applied (Tables 1 and 2).

Mombasa produced 17% more leaf and 18% more total DM than Tanzania in the establishment year (Table 1), and 30% more stem DM, 19% more leaf and 22% more total DM than Tanzania in the second year (Table 2). There was a significant interaction in the second year, with both cultivars having similar yields for stem, leaf and total DM at rates of 0, 20, 40 and 60 kg N/ha, while at higher rates, Mombasa produced more stem, leaf and total DM than Tanzania. Tanzania produced a higher percentage of leaf than Mombasa at rates of 20, 60 and 80 kg N/ha in the second year (Table 2).

Increasing rates of nitrogen significantly increased crude protein (CP) and NDF concentrations in stems and leaves of both cultivars (Tables 3). However, ADF levels in stems increased in Mombasa but were not affected in Tanzania, while levels in leaves remained almost constant for both cultivars (Table 3). Mombasa overall had significantly lower CP concentrations than Tanzania and higher concentrations of fiber.

Table 1. Effects of nitrogen fertilizer on dry matter production and leaf percentage of Mombasa and Tanzania guinea grasses in the establishment year.

Treatment (kg N/ha)		Stem dry matter	Leaf dry matter	Total dry matter	Leaf percentage
Per application	Total		(kg/ha)		(%)
0	0	741	2,895	3,636	79.6
20	60	1,088	4,033	5,121	78.7
40	120	1,644	4,941	6,585	75.0
60	180	2,598	5,704	8,302	68.7
80	240	2,669	6,031	8,700	69.3
100	300	3,156	6,578	9,734	67.5
LSD (P<0.05)		635	812	1,371	3.4
Cultivar					
Mombasa		2,156	5,433	7,589	71.6
Tanzania		1,809	4,627	6,436	71.8
LSD (P<0.05)		ns	469	792	ns
N x cultivar		ns	ns	ns	ns

Table 2. Effects of nitrogen fertilizer on dry matter production (kg/ha) and leaf percentage of Mombasa and Tanzania guinea grasses in the year after establishment.

Treatment (kg N/ha)		Stem dry matter		Leaf dry matter		Total dry matter		Leaf percentage	
Per application	Total	Mombasa	Tanzania	Mombasa	Tanzania	Mombasa	Tanzania	Mombasa	Tanzania
0	0	1,196	1,084	4,729	4,348	5,925	5,432	80.1	80.2
20	80	2,196	2,694	7,400	8,138	9,596	10,832	71.1	76.0
40	160	3,040	2,460	8,964	7,832	12,004	10,292	74.7	76.1
60	240	3,614	2,944	9,859	8,968	13,473	11,912	73.2	76.0
80	320	4,959	2,871	11,948	8,214	16,907	11,085	71.5	74.2
100	400	3,713	2,381	10,281	7,088	13,994	9,469	73.5	74.8
LSD (P<0.05)		1,153		1,809		2,891		2.3	

Table 3. Effects of nitrogen fertilizer on mean crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations (%) in stem and leaf of Mombasa (M) and Tanzania (T) guinea grasses over two wet seasons.

Treatment (kg N/ha)		CP				ADF				NDF			
Per application	Total	Stem		Leaf		Stem		Leaf		Stem		Leaf	
		M	T	M	T	M	T	M	T	M	T	M	T
0	0	2.8	3.1	6.3	6.7	40.0	40.5	36.3	36.7	67.7	67.3	62.2	62.4
20	60*/80**	2.8	3.6	6.1	7.1	41.6	40.5	36.3	36.9	69.3	67.9	63.0	63.1
40	120/160	3.2	3.4	6.4	7.0	43.2	40.8	36.0	36.9	69.9	68.4	63.9	62.9
60	180/240	3.3	4.1	7.0	8.0	42.9	40.8	36.2	37.1	69.9	68.1	63.9	63.0
80	240/320	4.2	4.6	7.8	8.6	42.6	40.6	36.6	36.5	69.6	69.4	64.2	63.7
100	300/400	4.9	5.8	9.0	10.4	43.0	40.8	35.8	36.5	69.4	69.3	63.1	63.9
LSD (P<0.05)		0.5		0.5		0.9		0.5		1.1		0.5	

* establishment year; ** second year.

Discussion

This study has shown that applying 40–60 kg N/ha to guinea grass every 40–45 days during the wet season will more than double the DM yield over that of unfertilized pasture. Even rates as low as 20 kg N/ha increased guinea grass DM yields by 40 and 80% in Years 1 and 2, respectively, above yields in control plots. While higher N rates increased DM yields further, there was no significant increase above 80 kg N/ha/application.

While these responses are outstanding, they are much lower than the increases of up to 250% recorded by Hare et al. (1999), when 20 kg N/ha was applied to *Paspalum atratum* on similar soils in Northeast Thailand every 30 days. These authors found that nitrogen applied as urea is quickly leached out of the soils with low organic matter content and urea must be applied frequently (every 30 days) in the wet season to be effective.

In both years, no further significant increase in total DM production of guinea grasses occurred after a total amount of 240 kg N/ha had been applied. This curvilinear response has not been found in Brazil, where in general, DM yields of Mombasa and Tanzania increased linearly with N fertilizer up to as high as 800 kg N/ha/yr (Freitas et al. 2005; Viana et al. 2014; Cecato et al. 2014a). Under irrigation and grazing in Brazil, Mombasa DM yields with 200 kg N/ha/yr were nearly twice those from pastures receiving no N (Cecato et al. 2014a). When the rate increased to 800 kg N/ha/yr, Mombasa DM yields were more than 4 times those from pastures receiving no N. In comparison, increases in annual DM yields of Tanzania under irrigation and grazing in Brazil were >80% with 200 kg N/ha/yr and 177% with 800 kg N/ha/yr compared with yields with no N (Viana et al. 2014).

In contrast with the curvilinear response of total DM to applied N in our study, the yield response (kg DM per kg N) decreased linearly from the lowest to the highest rate of total nitrogen applied (Table 4). The yield response was therefore not typically curvilinear (Humphreys 1987), with increased dressings of N giving progressively lower increases in DM per unit of N. In the second year, the yield response from applying the lowest rate of nitrogen was twice that of the response in the first year.

Table 4. Yield responses (kg DM/kg N) from applying nitrogen fertilizer to Mombasa and Tanzania guinea grasses.

Year	Total N applied (kg N/ha)	Increase in DM above control (kg DM/ha)	Yield response (kg DM/kg N)
1	60	1,485	24.7
	120	2,949	24.6
	180	4,666	25.9
	240	5,064	21.1
	300	6,099	20.3
2	80	4,535	56.7
	160	5,469	34.2
	240	7,013	29.2
	320	8,317	25.9
	400	6,052	15.1

The addition of nitrogen had interesting effects on composition of the forage, as increasing rates of N increased the amounts of both stem and leaf, but the percentage of leaf decreased with each application of N. This contrasts with findings in Brazil, where increased dressings of N reduced the percentage of Mombasa leaf in spring, and increased it in summer, but had no effect in autumn and winter (Cecato et al. 2014a).

The critical dietary CP level in tropical forages is 7% (Milford and Minson 1966), below which voluntary intake is depressed. In our study, nitrogen rates of 60–100 kg N/ha every 40−45 days were required to produce CP concentrations in leaves of guinea grass above 7%. At lower rates of 20–40 kg N/ha, rapid growth of the guinea plants occurred, producing a dilution effect, so that CP concentrations in leaves were similar to those in plants receiving no nitrogen. Intermediate N rates have also been found to increase DM yields but not CP concentration in Tanzania in Brazil, particularly during cooler periods of the year (Viana et al. 2014).

In considering the importance of crude protein in leaves, we suggest that applying 60 kg N/ha on each occasion appears a good compromise to achieve satisfactory DM yields, leaf percentage >70% (second year swards) and leaf CP concentrations above 7%.

Two previous research studies in this series on Mombasa and Tanzania found that Mombasa produced 23% more DM than Tanzania (Hare et al. 2013; 2014), due primarily to Mombasa having larger tillers and leaves than Tanzania (Hare et al. 2014). This study confirms the superior production of Mombasa, with Mombasa producing 17 and 19% more leaf and 18 and 22% more total DM than Tanzania, in the first and the second years, respectively. Mombasa also produced 30% more stem DM than Tanzania in the second year. It also supports earlier findings under grazing in Central and South America, where Mombasa produced 28–40% more DM than Tanzania (Cook et al. 2005).

Generally the quality of Tanzania has been found to be superior to Mombasa in terms of crude protein and fiber levels (Hare et al. 2013; 2014). This study supports that finding, particularly when higher rates of N were applied. However, it is Mombasa's greater DM production and tall structure which appeal to farmers in Thailand, who mainly grow forages in "cut-and-carry" systems and not as grazed pastures as in Central and South America (Viana et al. 2014; Cecato et al. 2014a, 2014b). The choice of which forage to plant will depend on whether quantity or quality of forage is the primary objective.

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References

Cecato U; Mari GC; Beloni T; Piotto VC; Lins TOA; Pinheiro AA. 2014a. Accumulation of dry matter and morphological composition of irrigated Mombaça grass with and without nitrogen fertilizer under grazing. Tropical Grasslands–Forrajes Tropicales 2:27–28. http://goo.gl/dZsso2

Cecato U; Iwamoto BS; Peluso EP; Mari GC; Pereira VV; Saute JM. 2014b. Animal performance on Tanzania grass pasture intercropped with Estilozantes Campo Grande or fertilized with nitrogen. Tropical Grasslands–Forrajes Tropicales 2:29–30. http://goo.gl/5fW1xK

Cook BG; Pengelly BC; Brown SD; Donnelly JL; Eagles DA; Franco MA; Hanson J; Mullen BF; Partridge IJ; Peters M; Schultze-Kraft R. 2005. Tropical Forages: An interactive selection tool. (CD-ROM). CSIRO and DPI & F, Brisbane, Queensland, Australia, CIAT and ILRI. www.tropicalforages.info/key/Forages/Media/Html/Panicum_maximum.htm

Freitas KP; Rosa B; Ruggiero JA; Nascimento JL; Heinemam AB; Ferreira PH; Macedo R. 2005. Evaluation of Mombaça grass *Panicum maximum* Jacq. under two different nitrogen rates. Acta Scientiarum Agronomy 27:83–89.

Hare MD; Suriyajantratong W; Tatsapong P; Kaewkunya C; Wongpichet K; Thummasaeng K. 1999. Effect of nitrogen on production of *Paspalum atratum* on seasonally wet soils in north-east Thailand. Tropical Grasslands 33:207–213. http://goo.gl/sLM6XK

Hare MD; Tatsapong P; Phengphet S. 2009. Herbage yield and quality of *Brachiaria* cultivars, *Paspalum atratum* and *Panicum maximum* in north-east Thailand. Tropical Grasslands 43:65–72. http://goo.gl/dJ0lDN

Hare MD; Phengphet S; Songsiri T; Sutin N; Stern E. 2013. Effect of cutting interval on yield and quality of two *Panicum maximum* cultivars in Thailand. Tropical Grasslands–Forrajes Tropicales 1:87–89. http://goo.gl/I15a7Z

Hare MD; Phengphet S; Songsiri T; Sutin N. 2014. Botanical and agronomic growth of two *Panicum maximum* cultivars, Mombasa and Tanzania, at varying sowing rates. Tropical Grasslands–Forrajes Tropicales 2:246–253. http://goo.gl/XJRXnx

Humphreys LR. 1987. Tropical pastures and fodder crops. 2nd Edn. Intermediate Tropical Agriculture Series. Longman Scientific & Technical, Harlow, Essex, UK.

Khemsawat C; Phaikaew C. 2007. Fresh grass cash crop farming in Thailand: A successful new enterprise for smallholder farmers. In: Hare MD; Wongpichet K, eds. Forages: A Pathway to Prosperity for Smallholder Farmers. Proceedings of an International Forage Symposium, Faculty of Agriculture, Ubon Ratchathani University, Thailand. p. 1–14.

Milford R; Minson DJ. 1965. Intake of tropical pasture species. Proceedings of the XI International Grassland Congress, São Paulo, Brazil, 1965. p. 814–822.

Mitsuchi M; Wichaidit P; Jeungnijnirund S. 1986. Outline of soils of the northeast plateau, Thailand: Their characteristics and constraints. Technical paper No. 1. Agricultural Development Research Center in Northeast, Khon Kaen, Thailand.

Nakamanee G; Srisomporn W; Phengsavanh P; Samson J; Stür W. 2008. Sale of fresh forage – a new cash crop for smallholder farmers in Yasothon, Thailand. Tropical Grasslands 42:65–74. http://goo.gl/0cYUI6

Phaikaew C; Nakamanee G; Pholsen P. 2007. Purple guinea: A high quality grass for forage and seed that improves smallholder income in Thailand. In: Hare MD; Wongpichet K, eds. Forages: A Pathway to Prosperity for Smallholder Farmers. Proceedings of an International Forage Symposium, Faculty of Agriculture, Ubon Ratchathani University, Thailand. p. 61–76.

Udchachon S; Boonpakdee W; Chomphoosao B. 1998. Yield of four forage species under high levels of fertiliser application and irrigation in the dry season. Annual Research Report 1998. Division of Animal Nutrition, Department of Livestock Development, Ministry of Agriculture and Cooperatives, Bangkok, Thailand. p. 255–271.

Viana MCM; Silva da IP; Freire FM; Ferreira MM; Costa da EL; Mascarenhas MHT; Teixeira MFF. 2014. Production and nutrition of irrigated Tanzania guinea grass in response to nitrogen fertilization. Revista Brasileira de Zootecnia 43:238–243. http://goo.gl/Mi7IbX

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