Fertilization Management to Optimize Yield and Quality of Bana Grass

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ABSTRACT

Fertilizers containing nitrogen (N) : phosphorus (P) : potassium (K) ratios of 46:0:0, 16:20:0 and 16:12:8 were applied in combinations. Each fertilizer in both the first and the second application was provided at a rate of 75 kg ha^{-1}. The trial comprised 3 defoliation frequencies at 45, 55 and 65 d according to a randomized completed block design. Forage in four 1-m^2 areas in each plot was cut and weighed in the field. Crude protein content (P<0.05) and dry matter (DM) yield (P<0.01) of bana grass were greater with an application of fertilizer containing higher proportions of N. At only a 45 d defoliation frequency, leaf proportions (P<0.01) and the 48 h in sacco DM and neutral detergent fiber digestibility (P<0.05) were greater when the initial application of N:P:K was 16:12:8. Application of a fertilizer containing 16:12:8 10 d after cutting, followed by 46:0:0 20 d before harvesting at a 45 d defoliation frequency resulted in optimum DM yield and quality.

Keywords: Bana grass, Fertilization, Defoliation, Leaf ratio

INTRODUCTION

Growing forage with a high yield potential and good quality is important to overcome limited supply of roughage during annual drought and reduce the amounts of concentrate needed for cattle farming in the tropics. Cultivars of napier grass have been improved for yield and quality. They differ widely in terms of botanical fractions and nutritive value (Islam et al., 2003). Bana grass (*Pennisetum purpureum x Pennisetum glaucum*) is a hybrid cultivar that grows well on many soil types and is more persistent and drought resistant than napier grass (Pieterse and Rethman, 2002). It also has a high yield potential with high crude protein (CP) and digestibility (Gupta and Mhere, 1997). However, DM yield of napier grass is positively correlated with soil fertility (Bogdan, 1977) and rainfall (Pieterse and Rethman, 2002), and digestibility is negatively correlated with maturity (Chen et al., 2006).

The decline in yield with time after cutting is well documented in tropical pastures and is attributed mainly to the removal of nutrients through harvesting, and to a lesser extent also to the tie-up of the soil N (Robbins et al., 1986), P and

K (Pieterse and Rethman, 2002) in below-ground parts. In general, P and K applied alone had little influence on plant growth (Ebdon et al., 1999), while nearly all grasses respond positively to N. As pasture yield is increased, so the response to an added nutrient will continue to a higher level of application. Luxury application of N, P and K will have a harmful effect on soil (Pieterse and Rethman, 2002) and environment. Of particular concern is the high dependence of intensive dairy farming on high inputs of fertilizer N, especially for systems based on grass. Reduced efficiencies of dietary N utilization as a result of additional fertilizer N were associated with an increase in N excretion in urine (Shingfield et al., 2001). In addition, the pH of top soil noticeably decreased in plots continuously (4 years) fertilized at a high rate of N (Pieterse and Rethman, 2002). A fertility program seldom applies N, P and K individually and research is limited concerning the influence of P and K on yield and quality of bana grass. However, the effects of N, P and K may be interactive on grass quality (Christians et al., 1981), while increasing defoliation frequencies improve quality, but reduce quantity. Split applications of an appropriate N:P:K combination may improve the efficiency of fertilizer applications and, therefore, might improve yield and quality of bana grass at an appropriate defoliation frequency.

MATERIALS AND METHODS

Location of the study area

A field experiment was conducted using a second year regrowth bana grass (*Pennisetum purpureum x Pennisetum glaucum*) pasture at the Udom Dairy Farm, Banyang, Ratchaburi Province (13° 19′ N, 99° 47′ E), which is in the western part of Thailand. During the experiment, monthly maximum and minimum temperatures ranged from 34.8 to 37.0°C and 22.3 to 25.6°C, respectively, and monthly rainfall ranged from 0 to 104.9 mm. The mean monthly maximum and minimum temperatures and rainfall for the trial site over the year are shown in Table 1. The experiment was located on a Kampaengsaen soil series classified as a Non-calcic Brown Soil (54.4% sand, 32.6% silt and 13% clay) with 2-3° slope. The pH of the top soil to the depth of 30 cm was between 6.0 and 6.5. The 30 cm soil layer contained 9.5 p.p.m. available P (Bray-2) and 59 p.p.m. available K (Ammonium acetate).

Table 1. The mean monthly maximum and minimum temperatures and rainfall for the trial site, 2010.

Month	Rainfall, mm	Temperature, °C	
		Maximum	Minimum
January	6.5	32.4	19.8
February	0	35.4	22.3
March	9.6	34.7	23.4
April	0.9	37	25.6
May	39.1	36.3	25.6
June	104.9	34.8	25.4
July	140.8	32.9	24.7
August	114.8	33.1	24.6
September	145.8	32.8	24.5
October	441.5	31.4	24.2
November	87.2	31.3	23.4
December	58.7	29.1	20.9

Fertilization treatments

The experiment consisted of two consecutive defoliation cycles from 1 February to 10 June 2010, which coincides with the annual drought period. A uniform pasture of bana grass was divided into 90 plots, each 2.25 m by 7.5 m. The trial comprised 3 replications and fertilizers containing N:P:K ratios of 46:0:0, 16:20:0 and 16:12:8 were applied in combinations. The trial comprised 10 fertilization combinations that were applied as follows: 1†=46-0-0, 46-0-0; 2†=46-0-0, 16-20-0; 3†=46-0-0, 16-12-8; 4†=16-20-0, 46-0-0; 5†=16-20-0, 16-20-0; 6†=16-20-0, 16-12-8; 7†=16-12-8, 46-0-0; 8†=16-12-8, 16-20-0; 9†=16-12-8, 16-12-8; 10†= No fertilizer. Fertilization treatments were applied twice – at 10 d after harvesting and 20 d before harvesting. Each fertilizer in both the first and second application was provided at a rate of 75 kg ha^{-1}. The trial comprised 3 defoliation frequencies at 45, 55 and 65 d according to a randomized completed block design. Sprinklers irrigated the plots at approximately 30 mm per 10 d interval. At harvesting, forage in four 1-m^2 areas in each plot was cut by hand at approximately 10 cm stubble height above the soil. Fresh yield and leaf proportion were then weighed in the field. The samples were dried at 103°C for dry matter determination. The samples were also dried at 60°C and ground to 1 mm for further chemical composition and 2 mm for *in sacco* digestibility analyses.

Laboratory and statistical analyses

Ether extract (EE), CP, ash, calcium (Ca), P and DM contents of the bana grass were measured according to the AOAC (1980). Neutral detergent fiber (NDF), acid detergent fiber (ADF), neutral detergent insoluble nitrogen (NDIN) and acid detergent lignin (ADL) were determined following the method of Van Soest et al. (1991). Total non-fiber carbohydrate (TNFC) was calculated by the equation: TNFC = 100 – CP – EE - (NDF-NDIN) - ash. Potassium content was analyzed using an Autoanalyser (SpectrAA 220 Varian, Aust.). Dry matter, NDF and CP *in sacco* digestibility were measured using the method of Orskov et al. (1980). The average yield from four 1-m^2 areas in each plot was used to represent the dry yield and leaf proportion in 1-m^2 area. For chemical composition, yield, leaf proportion and *in sacco* digestibility, the average of 2-cycle samples was used for all statistical measurements. Statistical analysis followed the linear modeling procedure of R (2009) and the difference between treatment means was analyzed by Least Squared Means.

RESULTS

Fertilizer treatment effects on yield and leaf proportions of bana grass are shown in Table 2. Dry matter yield of bana grass was greater ($P<0.01$) with an application of fertilizer containing higher proportions of N, irrespective of defoliation frequency. At a 45 d defoliation frequency, leaf proportions of bana grass were greater ($P<0.01$), both with an initial application of fertilizer containing N:P:K as 16:12:8 and without fertilization. However, at 55 d and 65 d defoliation frequencies, no significant differences were observed between fertilizer treatments for leaf proportions ($P>0.05$).

Table 2. The influence of application of various fertilizer combinations on dry matter yield and leaf proportions of bana grass.

	Fertilizer application										
Item	**1†**	**2†**	**3†**	**4†**	**5†**	**6†**	**7†**	**8†**	**9†**	**10†**	**SE**
45 d defoliation frequency											
Dry matter yield, t ha^{-1}											
Leat	7.56	7.00	6.63	6.88	3.44	3.07	7.41	3.75	3.69	2.06	0.26
Stem	7.31	6.56	6.44	6.69	3.25	2.93	5.91	3.13	2.88	1.63	0.47
Total	14.87^{a}	13.56^{b}	13.07^{b}	13.57^{b}	6.69^{c}	6.00^{c}	13.32^{b}	6.88^{c}	6.57^{c}	3.69^{d}	0.91
Leaf,%	50.84^{b}	51.62^{b}	50.73^{b}	50.70^{b}	51.42^{b}	51.17^{b}	55.63^{a}	54.51^{a}	56.16^{a}	55.83^{a}	1.99
55 d defoliation frequency											
Dry matter yield, t ha^{-1}											
Leaf	8.31	7.75	7.38	6.69	4.81	4.43	7.74	4.56	4.44	2.31	0.56
Stem	8.81	7.50	7.38	7.06	4.56	4.20	7.11	4.25	4.08	2.00	0.60
Total	17.12^{a}	15.25^{b}	14.76^{b}	13.75^{b}	9.37^{c}	8.63^{c}	14.85^{b}	8.81^{c}	8.52^{c}	4.31^{d}	1.51
Leaf,%	48.54	50.82	50.00	48.65	51.33	51.30	52.14	51.76	52.11	53.60	1.66
65 d defoliation frequency											
Dry matter yield, t ha^{-1}											
Leaf	10.00	9.06	9.13	8.75	6.38	6.56	8.88	6.69	7.31	2.75	0.66
Stem	11.19	9.81	10.18	9.63	7.88	8.63	10.06	8.00	7.69	2.75	0.74
Total	21.19^{a}	18.87^{b}	19.31^{b}	18.38^{b}	14.26^{c}	15.19^{c}	18.94^{b}	14.69^{c}	15.00^{c}	5.50^{d}	1.70
Leaf,%	47.19	48.01	47.28	47.61	44.70	43.19	46.88	45.54	48.73	50.00	1.71

Note: $^{a,\ b,\ c \text{ and } d}$ Means within a row without a common superscript letter differ ($P<0.01$). Split applications of fertilizers (10 d after and 20 d before harvesting) are as follows: 1†=46-0-0, 46-0-0; 2†=46-0-0, 16-20-0; 3†=46-0-0, 16-12-8; 4†=16-20-0, 46-0-0; 5†=16-20-0, 16-20-0; 6†=16-20-0, 16-12-8; 7†=16-12-8, 46-0-0; 8†=16-12-8, 16-20-0; 9†=16-12-8, 16-12-8; 10†= No fertilizer.

Crude protein contents of bana grass ranged from 46 to 102 g kgDM^{-1}. They were greater when fertilizers containing higher proportions of N were applied (Table 3). No significant differences were detected ($P>0.05$) between fertilizers containing P and K for contents of P (between 11.9 and 33.6 g kgDM^{-1}) and K (from 11.9 to 13.2 g kgDM^{-1}) of bana grass. Fertilizer applications did not have an effect ($P>0.05$) on contents of EE (12.0-28.0 g kgDM^{-1}), NDF (640-735 g kgDM^{-1}), ADF (380-479 g kgDM^{-1}), ADL (36-79 g kgDM^{-1}), ash (98-164 g kgDM^{-1}), TNFC (97-166 g kgDM^{-1}) and Ca (3.7-6.0 g kgDM^{-1}).

Table 3. The influence of application of various fertilizer combinations on crude protein contents of bana grass.

	Fertilizer application										
Item	**1†**	**2†**	**3†**	**4†**	**5†**	**6†**	**7†**	**8†**	**9†**	**10†**	**SE**
Crude protein contents, g kgDM^{-1}											
At 45 d cut	102^{a}	90^{b}	80^{b}	86^{b}	83^{b}	77^{b}	84^{b}	83^{b}	77^{b}	52^{c}	11
At 55 d cut	96^{a}	82^{b}	79^{b}	81^{b}	79^{b}	73^{b}	80^{b}	76^{b}	72^{b}	50^{c}	13
At 65 d cut	88^{a}	70^{b}	74^{b}	78^{b}	75^{b}	70^{b}	77^{b}	72^{b}	70^{b}	46^{c}	13

Note: $^{a,\ b,\ c\ \mathrm{and}\ d}$ Means within a row without a common superscript letter differ ($P<0.01$). Split applications of fertilizers (10 d after and 20 d before harvesting) are as follows: 1†=46-0-0, 46-0-0; 2†=46-0-0, 16-20-0; 3†=46-0-0, 16-12-8; 4†=16-20-0, 46-0-0; 5†=16-20-0, 16-20-0; 6†=16-20-0, 16-12-8; 7†=16-12-8, 46-0-0; 8†=16-12-8, 16-20-0; 9†=16-12-8, 16-12-8; 10†= No fertilizer.

Data for 48 h *in sacco* digestibility of bana grass are presented in Table 4. At 55 d and 65 d defoliation frequencies, no significant differences were found ($P>0.05$) between fertilizer treatments for the 48 h *in sacco* DM, CP and NDF digestibility. At a 45 d defoliation frequency, the 48 h *in sacco* DM and NDF digestibility were greater ($P<0.05$) when the initial application of N:P:K fertilizer was 16:12:8. However, the 48 h *in sacco* DM, NDF and CP digestibility were lowest for the unfertilized bana grass ($P<0.05$), irrespective of defoliation frequency.

Table 4. The influence of application of various fertilizer combinations on *in sacco* DM, CP and NDF digestibility of bana grass.

	Fertilizer application										
Item	**1†**	**2†**	**3†**	**4†**	**5†**	**6†**	**7†**	**8†**	**9†**	**10†**	**SE**
The 48 h *in sacco* digestibility, g kgDM^{-1} at a 45 d defoliation frequency											
Dry matter	589^b	590^b	583^b	579^b	590^b	581^b	630^a	628^a	624^a	531^c	22
Neutral detergent fiber	525^b	526^b	518^b	520^b	518^b	523^b	559^a	549^a	550^a	467^c	23
Crude protein	595^a	600^a	588^a	583^a	599^a	590^a	603^a	602^a	609^a	531^b	28
The 48 h *in sacco* digestibility, g kgDM^{-1} at a 55 d defoliation frequency											
Dry matter	550^a	543^a	546^a	539^a	542^a	549^a	564^a	552^a	559^a	499^b	29
Neutral detergent fiber	490^a	497^a	488^a	480^a	495^a	490^a	499^a	497^a	492^a	421^b	25
Crude protein	557^a	544^a	550^a	546^a	555^a	556^a	572^a	561^a	561^a	505^b	35
The 48 h *in sacco* digestibility, g kgDM^{-1} at a 65 d defoliation frequency											
Dry matter	501^a	497^a	504^a	491^a	503^a	507^a	520^a	511^a	508^a	444^b	30
Neutral detergent fiber	432^a	435^a	432^a	440^a	437^a	429^a	444^a	437^a	430^a	389^b	26
Crude protein	519^a	523^a	515^a	508^a	520^a	520^a	534a	516^a	518^a	449^b	40

Note: [a, b,c and d] Means within a row without a common superscript letter differ (P<0.05). Split applications of fertilizers (10 d after and 20 d before harvesting) are as follows: 1†=46-0-0, 46-0-0; 2†=46-0-0, 16-20-0; 3†=46-0-0, 16-12-8; 4†=16-20-0, 46-0-0; 5†=16-20-0, 16-20-0; 6†=16-20-0, 16-12-8; 7†=16-12-8, 46-0-0; 8†=16-12-8, 16-20-0; 9†=16-12-8, 16-12-8; 10†= No fertilizer.

DISCUSSION

In this study, multiple cuts of regrowth bana grass in an irrigated area were conducted during the drought period, presumably representing the response to fertilization on DM yield and leaf/stem ratio during rainy months. Normally, N is regularly applied while P and K are applied only once a year as basal fertilizers. However, luxury application of N, P and K fertilizer results in a decrease in pH of the topsoil (Pieterse and Rethman, 2002) and contributes to negative environmental impacts, such as excess P encouraging nuisance aquatic weed growth. For this reason, an appropriate N:P:K combination was applied in this study, as it was likely to improve the efficiency of fertilizer application in an irrigated area and, therefore, might improve yield and quality of bana grass at an appropriate defoliation frequency.

Effects of N, P and K individually on forage growth and quality as reported in the literature are primarily dependent on soil fertility, rainfall, maturity and forage variety. Powell and Fussell (1993) showed the importance of N and P in increasing forage yield and quality of pearl millet. Conversely, P and K had little influence on Kentucky bluegrass growth (Ebdon et al., 1999). Growth, quality and total nonstructural carbohydrate accumulation of Bermuda grass differed due to rates of N and K fertilization (Trenholm et al., 1998). Pieterse and Rethman (2002) demonstrated the influence of N in increasing DM yield of bana grass. In this study, DM yield of bana grass increased with increasing applications of fertilizer containing higher proportions of N, whereas increasing application of a fertilizer containing higher proportions of P and K had no effect.

Leaf proportion is important in determining forage nutritive values. In general, there is a progressive decline in leaf proportion as plants develop from a leafy vegetative stage toward maturity (Blaser, 1964). However, leaf and stem growth can vary due to environmental factors, particularly soil fertility (Batten et al., 1984). An optimum supply of N, P and K in combination is necessary for shoot growth (Ebdon et al., 1999), although the number of shoots increased with increasing N rate up to 200 kg ha^{-1} and decreased thereafter (Rusland et al., 1993). Maintenance fertilization with P and K to Brachiaria pasture is essential to sustain pasture productivity (Boddy et al., 2004). Furthermore, K fertilization has an important influence on root growth (Trenholm et al., 1998), having been shown to influence the recovery rate of Kentucky bluegrass turf from summer drought (Schmidt and Brueninger, 1981). At a 45 d defoliation frequency, leaf proportion of bana grass with an initial application (10 d after cutting) of 16:12:8 was significantly higher than those with an initial application of 46:0:0 and 16:20:0. Consequently, an initial application of fertilizer containing some K (i.e., 16:12:8) may be the optimum combination fertilizer for root and shoot growth of bana grass.

Nitrogen (Longnecker et al., 1993) and P (Rodriquez et al., 1998) are important in expansion of leaf area and P has an important effect on the rate of leaf primordial initiation in the stem apex and the size of individual leaves (Rodriquez et al., 1998). At a 45 d defoliation frequency, increasing yields of bana grass were associated with higher levels of N fertilization, probably associated with faster growth rate of stem length (Rusland et al., 1993). An initial application (10 d after cutting) of fertilizer containing 16:12:8 followed (20 d before harvesting) by 46:0:0 may produce the optimum growth rate of stem and leaf. Although the trial design makes it difficult to interpret interaction between nutrients, synergistic effects of N, P and K cannot be ignored. The increased leaf proportion was not found in bana grass at a 55 and 65 d defoliation frequency, because the effect of N on stem growth was probably greater than the effects of P on leaf growth.

The nutritive value of tropical grass is primarily determined by the CP content (Leng et al., 1993) and NDF digestibility (Flores et al., 1993), which are the major factors influencing voluntary intake rate by ruminants in the tropics. An increase in the rate of N fertilization will increase the content of CP of napier grass, although the same effect does not occur with P and K (Pieterse and Rethman, 2002). Adding P to brome grass (McCartney et al., 1998) and K to Coastal Bermuda grass (Cripps et al., 1989) increased P and K uptake in the herbage. A similar result of the CP content for fertilizers containing a higher proportion of N applied to bana grass was also observed in this study. In addition, under 45 d defoliation frequency, an initial application of fertilizer containing N:P:K as 16:12:8 resulted in an increase in DM and NDF digestibility. This increment possibly resulted from an increase in leaf proportion, as mentioned above. However, an increase in leaf proportion found in the unfertilized bana grass resulted in a decrease in DM, CP and NDF digestibility. This reduction is possibly due to higher contents of structural materials, such as NDF (684 vs 636 g $kgDM^{-1}$) and lignin (47 vs 40 g $kgDM^{-1}$), and a lower content of TNFC (138 vs

166 g kgDM^{-1}), as compared to those treatments with fertilization.

CONCLUSION

Increasing yields of bana grass were consistent with higher levels of N fertilization in all defoliation frequencies, while leaf proportion and DM and NDF digestibility at a 45 d defoliation frequency increased with an initial application of 16:12:8 fertilizer. At a 45 d defoliation frequency, an initial application (10 d after harvesting) of 16:12:8 fertilizer with the second application (20 d before harvesting) of 46:0:0 fertilizer resulted in an optimum DM yield, and an increase in leaf proportion and DM and NDF digestibility. More information is needed to improve protein nutrition, while reducing fertilizer application, and this could be done by growing bana grass in association with a legume such as cowpea.

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