Research Article

Effects of Levels of Sulfur Fertilizer on Growth of *Digitaria eriantha* Grass

Auraiwan Isuwan[1*], Jeerasak Saelim[2] and Somsak Poathong[3]

[1]*Faculty of Animal Sciences and Agricultural Technology, Silpakorn University, Petchaburi Campus, Cha-Am, Petchaburi, Thailand*
[2]*Forage Research Section, Division of Animal Nutrition, Department of Livestock Development, Bangkok, Thailand ,*
[3]*Petchaburi Animal Nutrition Research and Development Center, Cha-Am, Petchaburi, Thailand*
**Corresponding author. E-mail address: auraiwan_i@hotmail.com*

Received June 6, 2007; Accepted October 1, 2007

Abstract

This study was aimed to determine and evaluate the effects of sulfur fertilizer application on the quantity and chemical composition of *Digitaria eriantha* grass. The experiment was conducted at Petchaburi Animal Nutrition Research and Development Center, Petchaburi, Thailand, during August to October, 2006. Treatments consisted of 0, 12 and 24 kgS/rai applications in the form of ammonium sulfate and were arranged in randomized complete block with 4 field blocks as replication. Grass was sampled at 2, 4, 6 and 8 weeks of regrowth to determine biomass accumulation over maturation period between and within treatments. The samples of 6-week old grass were subjected to chemical composition evaluation.

The results showed that there was a significant linear correlation between levels of S fertilizer application and biomass accumulation of 2-week old grass. Biomass accumulation was significantly increased with the increasing rates of S fertilizer applications (120.56, 176.48 and 200.62 kgDM/rai at 0, 12 and 24 kgS/rai, respectively). Sulfur (0.09, 0.17 and 0.18 %DM) and crude protein (6.10, 8.22 and 10.25 %DM) concentrations and crude protein yield (40.48, 61.35 and 76.00 kg/rai) had increased linearly with the increasing levels of sulfur fertilizer application of 0, 12 and 24 kgS/rai, respectively. The result of this study showed that quality of grass can be improved through S fertilizer application. There is a need for further study on the effect of S application on ruminant performance to improve pasture management. This information can be used to make sensible recommendation for sustainable pasture management for animal production.

Key Words: *Digitaria eriantha*; Sulfur fertilizer

Introduction

Sulfur (S) deficiency in crop productions has become increasingly widespread throughout the world. It is a result of a combination of factors such as decreased atmospheric inputs of S, increased crop yields and changed in the use of S-containing fertilizers to S-free or low S fertilizers (Scherer, 2001). An insufficient S supply can affect yield and quality of the crop because S is essential for the formation of certain amino acids, methionine and cystein, for protein and enzyme synthesis. Sulfur is related to plant growth and nutritive values in alfalfa forages by promoting vegetative growth and enhancing protein and chlorophyll content, dry matter digestibility and intake of animal feeds (Wang et al., 2003). Rechcigl, 1991 reported on a 3 years study investigating the effect of ammonium sulfate fertilization of bahiagrass (*Paspalum notatum*) and found that the application of S in form of ammonium sulfate resulted in higher forage S concentrations (0.23 and 0.30% for applications of 86 and 174 kg of S/ha equilibrium to 13.74 and 27.84 kgS/rai, respectively) compared with bahiagrass fertilized with ammonium nitrate (0.10% S). Although the quantity of forage available to the ruminant is important, the quality and nutritive values are essential to maintain health, growth and reproduction of livestock. The lower the forage quality, the more the animal has to take in to achieve the same production volume.

Sulfur fertilizers have been shown to increase both pasture yield and the concentration of S in the forage (Rechcigl, 1991). Sulfur fertilizer will also alter plant growth rate and plant composition and this may affect the nutritive values. This effect was first shown in a study by Rees et al., 1974 who showed that the voluntary feed intake by sheep of immature Pangola grass (*Digitaria eriantha*) grown with application of S fertilizer had increased by 44% and DM digestibility by 5%. A simple S deficiency accounted for 63% of the difference in voluntary intake and all the difference in digestibility. Low ruminal S concentration can also depress microbial growth and reduce fiber digestion (Kandylis, 1984). The concentration of sulfur in the rumen that limits growth of ruminal microorganisms was at 1 mgL^{-1} and there was evidence that sulfur can be a limiting factor in protein synthesis by bacteria (Van Soest, 1994). Apart from affecting the quantity of microbial protein synthesis, nutrient availability can affect the composition of microbial cells. Weston et al., 1989 proposed that the level of amino acids containing S (methionine, cystein and cysteine) in ruminal microbes might be reduced by a deficiency of S.

The objectives of this study were to determine and evaluate the effects of sulfur in the form of ammonium sulfate fertilization on dry matter yield and chemical composition of Pangola grass.

Materials and Methods

Location and soil characteristics

The experiment was conducted at Pangola grass field of Petchaburi Animal Nutrition Research and Development Center, Amphor Cha-Am, Changwat Petchaburi, in Hub-Kapong Soil Series (LDD., 2005) (coarse-loamy, siliceous, Ustoxic Dystropepts). General characteristics of this soil have been previously described by Sengsai et al., 2006. It was slightly acid ($pH_{water\ 1:1}$ 6.4), low in organic matter content (10.01 gkg^{-1}), with exchangeable potassium, calcium, magnesium and phosphorus concentrations of 21.7, 93.6, 580.2 and 58.2 $mgkg^{-1}$, respectively.

Treatments and Sample Collection

A 2-year old stand of Pangola grass (*Digitaria eriantha*) field was divided equally into 4 field blocks according to the slope. Each block was sub-divided into 3 plots (4x5 m^2) and each plot was separated by 1.5 m spacing. Treatments were arranged into randomized complete block design with 4 field blocks as replication. Three treatments consisted of 1) no sulfur application (control) 2) sulfur application at the rate of 12 kgS/rai and 3) sulfur application at the rate of 24 kgS/rai. All plots were fertilized with basal plant nutrients at 20 kg P_2O_5/rai, 20 kg K_2O/rai and 21 kg N/rai at the start of the experiment. Rate of each fertilizer application was presented in Table 1. Treatment pastures were applied by ammonium sulfate and urea before the experiment had started, while urea was a sole nitrogen source in the control plot.

Biomass accumulation of Pangola grass was sampled for four times between August 28, 2006 and October 23, 2006. It was sampled at 2 weeks interval, the first sampling was conducted on September 11, the 2nd on September 25, the 3rd on October 9 and the

Table 1 Type and quantity of fertilizer used in the experiment (kg/rai)

Treatment	Triple super phosphate ($46\% P_2O_5$)	Potassium chloride ($60\% K_2O$)	Ammonium sulfate (21% N, 24% S)	Urea (46% N)
No sulfur application	43.5	33.3	-	45.7
12 kgS/rai application	43.5	33.3	50.0	20.7
24 kgS/rai application	43.5	33.3	100.0	-

4^{th} on 23 October by clipping five 0.16 m^2 quadrates per plot at approximately 3 cm stubble height with scissor. According to random sampling, no area within plot was clipped more than once so that all clipped forage was original regrowth. All clipped forage samples were weighed and dried individually under hot air oven at 60 °C for 48 hr. Dry weights for each quadrate sample were used to estimate available forage yield. All of weeds and death materials were separated by hand and removed before available forage calculation and subsequent analysis. Soil sampling was conducted at the end of experiment in which it was dried in shed, ground though a 1 mm screen and stored in bottle for S concentration analysis.

Laboratory determinations

The samples of all regrowth ages were ground through a 1-mm screen in a Wiley mill. The dry matter (DM) of all regrowth samples was analyzed for grass DM yield determination. The crude protein (CP) concentration and neutral- (NDF) and acid- (ADF) detergent fiber of 6 weeks of regrowth samples were analyzed as described by the AOAC., 1980 and Van Soest et al., 1991, respectively. CP concentration was calculated as the percentage of N content in the sample multiplied by a factor of 6.25. Sulfur concentration in plant and soil were analyzed by Turbidimetric method (Van Lagen, 1996)

Statistical Analyses

Analysis of variance (ANOVA) was performed using PROC GLM of SAS (SAS, 1998) for a randomized complete block design to determine the effect of sulfur levels and regrowth age (4 regrowth ages) on dry matter yield of grass by using a single-df orthogonal contrast for linear, quadratic and cubic. Chemical compositions of grass at 6 week of regrowth age and soil sulfur concentration were analyzed using PROC GLM. Means difference was performed using Duncan's New Multiple Range Test.

Results and Discussion

Sulfur concentration in the soil

Sulfur concentration in soil at the end of experiment had increased linearly (Linear, p=0.0277), according to the level of S fertilizer applications. However, there was no significant difference between

Table 2 Effect of sulfur application level on sulfur concentration in soil at the end of experiment

	Sulfur application rate (kgS/rai)			SEM	Contrast	
	0	12	24		Linear	Quadratic
S in Soil ($mgkg^{-1}$)	6.13^{b}	15.54^{a}	17.85^{a}	2.39	0.0277	0.1741

SEM = standard error of the mean, N = 4

[a b c] Means with different superscripts within column are significantly different (p<0.05)

soil applied with 12 and 24 kgS/rai (Table 2).

Dry matter yield accumulation

The effects of the rates of sulfur and age of regrowth on DM yield are shown in Table 3. In term of the effect of sulfur application level at each week of regrowth age, it was found that there was a linear responsibility (p=0.0218) between sulfur application and DM yield on 2 weeks of regrowth age ranging from 120.56 to 200.62 kgDM/rai. However, no correlation was observed in other regrowth age. Furthermore, there are correlation between regrowth age and plant biomass accumulation within each sulfur application level (cubic, p=0.0107, 0.0052 and 0.0020 for 0, 12 and 24 kgS/rai application rate, respectively). The cubic effect may be caused by the average growth stage on the final harvest dates that had included both fully mature and other less-developed tillers. Ogden et al., 2005 reported that the growth of the new tillers late in the maturing period also had affected the cubic effect. According to the cubic effect within treatment, there was a fluctuation in biomass accumulation, for example in plot which received no S application. The dry matter accumulation rate had reduced to 9.85 kg/rai between week 4 and week 6 of age and again had increased to at least 283.35 kg/rai from week 6 to week 8 of age (Table 3).

Crude protein yield and chemical composition concentration of 6-week old grass

Dry matter, crude protein yields and chemical compositions of 6-week old grass which are affected by sulfur fertilizer applications are shown in Table 4. CP concentration was strongly influenced by sulfur application. It was also observed that CP yield and CP concentration of 6-week old grass had increased with the increasing level of sulfur fertilizer application (Linear, p=0.0010 and p=0.0012, respectively). Surprisingly, CP content had increased to 134.75 and 168.03% comparing to the control when sulfur fertilizer was applied at 12 and 24 kgS/rai, respectively. Ahmed et al., 1995 reported nitrogen concentration of forage sorghum (*Sorghum bicolor L.*) had increased from 1.47 to 1.55% when 138 kgS/ha (equilibrium to 22.08 kgS/rai) was applied.

Table 3 Effect of sulfur application levels and regrowth age on dry matter yield of Pangola grass

Sulfur application rate (kgS/rai)	Dry matter yield (kg/rai) at week 2	week 4	week 6	week 8	SEM¹	Contrast* L³	Q⁴	C⁵
0	120.56	651.80	661.65	945.27	55.43	0.0001	0.0524	0.0107
12	176.48	676.00	745.69	1045.25	40.19	0.0001	0.0346	0.0052
24	200.62	673.45	744.00	1141.12	37.92	0.0001	0.3442	0.0020
SEM²	18.40	25.98	53.01	104.23				
Contrast#								
L³	0.0218	0.5771	0.3141	0.2323				
Q⁴	0.5074	0.6888	0.5336	0.9877				

SEM¹ = Standard error of the mean of fertilizer level effect, N = 4

SEM² = Standard error of the mean of grass age effect, N = 4

³ = Linear ⁴ = Quadratic ⁵ = Cubic * = responsibility of regrowth age effect at each sulfur fertilizer rate

= responsibility of sulfur fertilizer effect at each regrowth age

Grass applied with 24 kgS/rai had 10.25% of CP concentration (Table 4), whereas Sengsai et al., 2006 had reported that the CP concentration of 6- week-old Pangola grass grown at this site was 6.3%. At this regrowth age, NRC., 1988, Juarez Lagunes et al., 1999, Fox et al., 2000 and Tedeschi et al., 2002 had reported that Pangola grass contained 7.1, 7.0, 8.7 and 7.0% CP, respectively. Havlin et al., 2005 supported that S mineral related to plant protein synthesis because it is a component of S-containing amino acid in chlorophyll and coenzyme which was linked to protein metabolism (thiamine and pyrophosphate, for instant). Even though there was significant different among means of NDF concentration, the value narrowly ranged from 65.00 to 69.30%. However, there was no significant different among ADF values (Table 4).

Although there was no significant difference between 12 and 24 kgS/rai application on S concentration, sulfur concentration of grass applied with these two levels was significantly higher than that of the control treatment. No difference response in plant S concentration was observed from both rates of application. This may be contributed to the nature of plant that can absorb S only at optimal level. Kanwar and Mudahar, 1986 reported that S recovery from S sources applied to the soil was dependent on a number of factors, such as nature of the crop and the soil condition. Pasricha et al., 1977 compared the effect of levels of S application (25 and 50 ppm) on S recovery rate of Maize and found that there was no difference in plant S concentration. Sulfur concentrations of grass applied with S fertilizer had increased up to two times comparing to the control treatment (Table 4). This was consistent with the report of Arthington et al., 2002 who reported that S concentration in bahiagrass fertilized with ammonium sulfate was greater than those which were unfertilized and fertilized with ammonium nitrate. Hardt et al., 1991 also reported that applying ammonium sulfate to oat-wheat pastures had also increased forage S concentration at least 27%.

Besides an increasing of concentration of CP and S of grass, Akin et al., 1983 reported that applying S to *Digitaria pentzii* resulted in an increasing number of rumen fungi. Moreover, it was found that leaf blades from fertilized forage were twice more fragile than

Table 4 Effect of sulfur application levels on yield and chemical composition of Pangola grass at 6 weeks of regrowth age

Sulfur application rate (kgS/rai)	Dry matter yield	Crude protein yield	DM	CP	NDF	ADF	S
	(kg/rai)		(%)	(%DM)			
0	661.65	40.48^{c}	21.24	6.10^{c}	65.00^{b}	32.97	0.09^{b}
12	745.69	61.35^{b}	19.79	8.22^{b}	69.30^{a}	34.41	0.17^{a}
24	744.00	76.00^{a}	21.48	10.25^{a}	65.45^{b}	33.13	0.18^{a}
SEM	53.01	4.22	2.63	0.51	0.77	0.36	0.01
Contrast							
Linear	0.3141	0.0010	0.9501	0.0012	0.6926	0.7704	0.0025
Quadratic	0.5336	0.5692	0.6423	0.9460	0.0048	0.0213	0.0831

SEM = standard error of the mean, N = 4

$^{a\,b\,c}$ Means with different superscripts within column are significantly different (p<0.05) that of unfertilized forage. Therefore, fragility of this material may contribute to the greater intake of S - fertilized forage by sheep.

Conclusion

This study showed that sulfur fertilizer application to Pangola grass pasture not only improved CP and S concentration but also increased CP yield per area unit of 6-week old grass. Even though, Hub Kapong Soil Series was extremely poor in fertility and subsequently contributed to the low quality of grass, the result of this study showed that quality of grass can be improved through S fertilizer application at both rate of 12 and 24 kgS/rai. Sulfur application at the rate of 24 kgS/rai provided the highest protein yield per area unit. There is a need for further study on the effect of S application on forage quality and its effect on the favorability of this material to animal production.

Acknowledgement

Petchaburi Animal Nutrition Research and Development is acknowledged for providing collective facilities and pasture constructive instruments. The authors thank Mr. Panlop Mungmee, Miss Sakunee Choorasri and Mr. Surat Choopanya, for their help on collecting data and chemical analysis.

References

AOAC. (1980) *Official Methods of Analysis.* 13th edition. Washington, D.C. USA.

Ahmed, M. R., Allen, V. G., Fontenot, J. P., and Hawkins, G. W. (1995) Effect of sulfur fertilization on chemical composition, ensiling characteristics and utilization by lambs of sorghum silage. *Journal of Animal Science* 73: 1803-1810.

Akin, D. E., Gordon, G. L. R., and Hogan, P. (1983) Rumen bacteria and fungal degradation of *Digitaria pentzii* growth with or without sulfur. *Applied Environmental Microbiology* 46: 738-748.

Arthington, J. D., Rechcigl, J. E., Yost, G. P., McDowell, L. R., and Fanning, M. D. (2002) Effect of ammonium sulfate fertilization on bahiagrass quality and copper metabolism in grazing beef cattle. *Journal of Animal Science* 80: 2507–2512.

Fox, D. G., Tylutki, T. P., Van Amburgh, M. E., Chase, L. E., Pell, A. N., Overton, T. R., Tedeschi, L. O., Rasmussen, C. N., and Durbal, V. M. (2000) *The Net Carbohydrate and Protein System for Evaluating Herd Nutrition and Nutrient Excretion. CNCPS version 4.0 November 3rd, 2000.* Animal Science Mimeo 213 Department of Animal Science, Cornell University 130 Morrison Hall, Ithaca, New York 14853-4801. 237 pp.

Hardt, P. F., Ocumpaugh, W. R., and Greene, L. W. (1991) Forage mineral concentration, animal performance and mineral status of heifers grazing cereal pasture fertilized with sulfur. *Journal of Animal Science* 69: 2310-2320.

Havlin, J.L., Beaton, J.D., Tisdale, S.L., and Nelson, W.L. (2005) Soil Fertility and Fertilizers: An introduction to nutrient management. Pearson Education, Inc., New Jersey.

Juarez Lagunes, F. I., Fox, D. G., Blake, R. W., and Pell, A. N. (1999) Evaluation of tropical grasses for milk production by dual-purpose cows in Tropical Mexico. *Journal of Dairy Science* 82: 2136–2145.

Kandylis, K. (1984) Toxicology of sulfur in ruminants: A review. *Journal of Dairy Science* 67: 2179– 2187.

Kanwar, J. S. and Mudahar, M. S. (1986) *Fertilizer Sulfur and Food Production.* Martinus Nijhoff/ Dr W. Junk Publishers, Dordrecht, The Natherland.

LDD. (2005) Soil of Thailand. [Online URL: http:// www.ldd.go.th/thaisoils_museum/INDEX. HTM] accessed on July 22, 2006. (in Thai)

NRC. (1988) *Nutrient Requirements of Dairy Cattle.* 6th ed. National Academy Press, Washington, DC.

Ogden, R. K., Coblentz, W. K., Coffey, K. P., Turner, J. E., Scarbrough, D. A., Jennings, J. A., and Richardson, M. D. (2005) Ruminal in situ disappearance kinetics of dry matter and fiber in growing steers for common crabgrass forages sampled on seven dates in northern Arkansas. *Journal of Animal Science* 83:1142–1152

Pasricha, N. S., Randhawa, N. S., Bahl, G. S., and Dev, G. (1977) Sulphur uptake and dry matter production in Maize at different growth stage as affected by native and applied sulphur. *Indian Journal of Agricultural Sciences* 47: 336-340.

Rechcigl, J. E. (1991) Sulphur fertilization improves bahiagrass pastures. *Better Crops Plant Food* 75:22–24.

Rees, M. C., Minson, D. J., and Smith, F. W. (1974) The effect of supplementary and fertilized sulphur on voluntary intake, digestibility, retention time in the rumen, and site of digestion of pangola grass in sheep. *Journal of Agricultural Science* 82: 419–422.

SAS. (1998) SAS/STAT® User's Guide, Release 6.03 Edition. SAS Institute Inc., Cary, NC, USA.

Sengsai, A., Chararachata, P., and Poathong, S. (2006) Effects of cutting interval and grass species on yield and quality of hay. *Annual Research Report 2006.* Animal Nutrition Division, Dapartment of Livestock Development, Thailand. 104-120. (in Thai)

Scherer, H. W. (2001) Sulphur in crop production — invited paper. *European Journal of Agronomy* 14: 81–111.

Tedeschi, L. O., Fox, D. G., Pell, A. N., Lanna, D. P. D., and Boin, C. (2002) Development and evaluation of a tropical feed library for the cornell net carbohydrate and protein system model. *Scientia Agricola* 59: 1-18.

Van Lagen, B. (1996) Soil analysis. In *Manual for Soil and Water analysis* (eds. P. Buurman, B. Van Lagen and Velthorst, E.J.) pp. 1-166. Backhuys Publishers, Leiden, Netherlands.

Van Soest, P. J. (1994) *The Nutritional Ecology of the Ruminant.* 2nd edition. Cornell University Press. Ithaca, NY. 476 pp.

Van Soest, P. J., Robertson, J. B., and Lewis, B. A. (1991) Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3583-3597.

Wang, Y. F., Wang, S. P., Cui, X. Y., Chen, Z. Z., Schnug, E., and Haneklau, S. (2003) Effects of sulphur supply on the morphology of shoots and roots of alfalfa (*Medicago sativa* L.). *Grass and Forage Science* 58:160–167.

Weston, R. H., Lindsay, J. R., Purser, D. B., Gordon, G. L. R., and Davis, P. (1989) Feed intake and digestion responses in sheep to the addition of inorganic sulfur to a herbage diet of low sulfur content. *Australian Journal of Agricultural Research* 39: 1107-1119.