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Effects of Urea and Cattle Manure on Yield and Quality of Signal Grass (*Brachiaria decumbens* Stapf. cv. Basilisk) in Northeast Thailand

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Abstract: This experiment was carried out on Korat soil series (Oxic Paleustults) at Khon Kaen University Experimental Farm, Northeast Thailand during the 1998 to 2001 to investigate effects of urea and cattle manure application rates on yield and quality of Signal grass (*Brachiaria decumbens* Stapf. cv. Basilisk). A Randomised Complete Block Design with four replications was used. The treatments include control, urea @ 125 kg ha^{-1}, Cattle Manure (CM) @ 3.125, 6.25, 12.5 and 25 t ha^{-1}. The results showed that total dry matter yield in the rainy season was significantly higher for urea treatment than manure treatment but in the dry season a reverse result was attained, i.e. the highest rate of cattle manure gave significantly greater total dry matter yield than the rest. Cattle manure @ 25 t ha^{-1} and urea treatments gave the highest grand total dry matter yields where both were similar. There was a highly significant effect due to year and treatment on dry matter yield but none for year x treatment. Crude Protein contents (CP), in all cases, were significantly higher for the dry season than the rainy season. Urea and the highest rate of cattle manure treatments in the rainy season gave the highest CP contents but in the dry season CP content was higher for urea than cattle manure. There was a significant effect due to urea and cattle manure on Neutral Detergent Fibre content (NDF) in the dry season but none for the rainy season. Significant effect due to treatments on ADF content was also found for both seasons, rainy and dry. A highly significant effect due to treatments on DMD was attained only for the growth in the rainy season but none for the dry season.

Key words: Cattle manure, dry matter yield, forage quality, Signal grass, urea

INTRODUCTION

Signal grass (*Brachiaria decumbens* Stapf.), an important grass species for pasture development has its outstanding features in both production and adaptability. This grass species requires a well-drained soil condition with high fertility to produce maximum output of Dry Matter Yield (DMY) for livestock production[1,2]. Most soil series in Northeast Thailand are sandy loam soils with a high degree of acidity, low amount of nutrient and organic matter contents[3,4]. The northeastern region is one of the four important regions of the country. It has one third of both land area and population, most of the plain area have an elevation of approximately 200 m above sea level and up to 800-1, 300 m for mesa mountain of the Phukradueng National Park (a mountain with a large plain area) where, most area is occupied with a dense forest[4]. A large land area of the region is suitable for pasture establishment for livestock production, thus many growers have paid their attention to establish their grazing pasture fields for their herds both beef and dairy. Korat soil series (Oxic Paleustults) was used for the Signal grass experiment due to its plentiful in the region. This soil type is, more or less, having a similar texture and soil properties as that of the Yasothon soil series (Oxic Paleustults), it is a poor soil series in the region[4-7]. This poor soil possesses low pH and N content where it normally causes a severe effect on the production of pasture and other cash crops[5,6,8]. Thinnakorn *et al.*[9] grew the Signal grass on Pakchong soil series (Oxic Paleustults) reported that DMY and crude protein contents significantly increased with an increase in urea application rate. Therefore, it is essential to investigate the effects due to urea and Cattle Manure (CM) application rates on DMY and quality of the Signal grass on Korat soil series (Oxic Paleustults). The results attained may be useful for growers of pasture crops in the northeastern region of Thailand.

MATERIALS AND METHODS

This Signal grass (*Brachiaria decumbens* Stapf. cv. Basilisk) experiment was carried out at the Experimental

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Farm, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand for 3 years during the 1998 to 2001. Dolomite [$CaCO_3.MgCO_3$] contained 31% Ca and 21% Mg at a rate of 3.75 t ha^{-1} together with sulfur derived from gypsum at a rate of 6.25 kg S ha^{-1} were applied as a basal dressing into the soil before ploughing. One week after the application of both dolomite and sulfur, the land was ploughed twice followed by harrowing once. The land was divided into plots according to their respective treatments. Each plot has a dimension of 3x3 m with a walking path of 1 m between the plots and 1.5 m between the blocks. Seeds of the Signal grass were sown into rows by hand at the distances between rows and within rows of 50x10 cm, respectively. After sowing, carbofuran 3% G insecticide was applied into the plots at a rate of 37 kg ha^{-1} to prevent insect pest damages followed by the spraying of atrazine herbicide at a rate of 2.2 kg ha^{1-} to control pre-emergence of weed seeds. Two weeks after emergence, seedlings were thinned out leaving only one seedling/drill. The Signal grass seedlings were allowed to grow under rain-fed conditions without any interference for one year and then the grass in each plot was cut out at 10 cm above ground level followed by the application of the various treatments into their respective plots where appropriate. Soil samples were taken to the depth of approximately 15 cm from each replicated plot. Soil samples were taken twice, i.e. before the allocation of the treatments into the plots and the second sampling was taken at the third cutting for dry matter yield. The experiment was laid in a Randomised Complete Block Design with 4 replications. The treatments used include control (T_1), @ of 125 kg ha^{-1} (T_2), Cattle Manure (CM) @ of 3.125 (T_3), 6.25 (T_4), 12.50 (T_5) and 25 t ha^{-1} (T_6). Urea and each rate of cattle manure were divided into four equal portions. The first portion was applied on the 22nd July 1999 and then the other three portions were applied to the plots at 45-day intervals, i.e. after each harvest for dry matter yields. Urea and cattle manure rates were applied only in the rainy season within the three years experiment. The Signal grass samples within a quadratic area of 0.5x0.5 m were taken for dry weight and fodder quality determinations. They were cut at 10 cm above ground level and four quadratic areas were cut from each plot. The Signal grass plants those were not included in the quadratic areas were also cut out but discarded. The cutting for DMYs was carried out three times in the rainy season and twice in the dry season (22nd July, 5th September and 20th October 1999 for the rainy season and 5th December 1999 and 28th April 2000 for the dry season). For the second year samplings, the grass samples were taken for four times in the rainy season (26th June, 9th August. 22nd September and 4th November 1999) and two times for the dry season (5th April and 16th May 2000). For the third year period, four times in the rainy season (26th June, 9th August, 18th September and 1st November 2000) and once in the dry season (17th May 2000).

The soil samples were analysed for soil pH (1: 2.5, soil: water by volume), total soil nitrogen and organic matter[10,11]. Available phosphorus was determined by Bray II extraction and Colorimetric methods[10,12,13]. Extractable potassium was carried out with the use of NH_4OAc Extraction and Flame photometry[14]. The Signal grass samples of the first year experiment were used for the determination on feed quality. All of the grass samples were oven dried at 60°C for 72 h and then weighed out for DMY. For feed quality, the oven dried grass samples were ground to pass through a 1 mm screen grinder. The ground samples were used for the analysis on chemical components and Dry Matter Degradability (DMD). Crude Protein (CP) was determined by Kjeldahl method. Neutral Detergent Fibre (NDF) and Acid Detergent Fibre contents (ADF) were also analysed. DMD determination was carried out using nylon bag technique in cattle rumen for 48 h[15,16]. The collected data were statistically analysed using a SAS computer programme[17,18].

RESULTS

Rainfall and soil analysis data: The results on the amount of rainfall of the 4-year experimental period showed that total amount of rainfall were 1,250.3 mm for the initial year (1998); 1,241.2; 1,783.8 and 1230.3 mm for the year 1999; 2000 and 2001, respectively. The initial soil analysis data showed that initial mean values of soil pH, Organic Matter (OM), total soil nitrogen (N), available Phosphorus (P) and extractable Potassium (K) were 4.4, 1.0, 0.05%, 5.5 and 13 ppm, respectively. At the third cutting in the first year sampling period, mean values of soil pH ranged from 5.45 to 5.85 and OM from 1.20 to 1.59% for T_2 and T_6, respectively (Table 1). N ranged from 0.047 to 0.059%, P from 15.25 to 28.75 ppm and K from 13.00 to 117.25 ppm for T_2 and T_6, respectively. There were significant effects due to urea and cattle manure treatments on soil N, P and K.

First year dry matter yields: For first DMY of the Signal grass in the rainy season, the results showed that DMY of the first cutting ranged from 640 to 1,121 kg ha^{-1} for T_1 and T_2, respectively. Urea application significantly increased DMY over the control treatment. However, CM treatments gave a similar DMY to control (Table 2). A similar pattern on DMY to the first cutting was found with

Table 1: Soil analysis data of Korat soil series (Oxic Paleustults) at the 3rd cutting of the first year sampling period of the Signal grass as influenced by urea and cattle manure application rates

Treatments	pH (1: 2.5)	OM (%)	Total soil N (%)	Available P (ppm)	Extractable K (ppm)
T_1	5.63	1.24	0.047^{b}	12.25^{abc}	26.50^{cd}
T_2	5.45	1.20	0.048^{b}	15.25^{c}	13.00^{d}
T_3	5.65	1.31	0.051^{ab}	20.50^{abc}	40.50^{c}
T_4	5.85	1.31	0.052^{ab}	19.00^{bc}	68.50^{b}
T_5	5.85	1.48	0.055^{ab}	25.50^{ab}	82.75^{b}
T_6	5.85	1.59	0.059^{a}	28.75^{a}	117.25^{a}
Significant	NS	NS	*	*	**
LSD 0.05	-	-	0.009	8.64	23.84
CV (%)	6.34	14.12	11.88	26.02	27.23

Letter(s) within the columns indicate LSD, NS = non-significant, * = significant at $p \leq 0.05$, ** = significant at $p \leq 0.01$, CV = coefficient of variation

Table 2: Mean values of dry matter yields, total dry matter yields in the rainy and dry seasons of five cuttings and total grand yields (kg ha^{-1}) of the Signal grass of the first year sampling period as influenced by urea and cattle manure application rates

	Rainy season			Dry season		Total DM yield		Grand
Treatments	1st	2nd	3rd	4th	5th	Rain	Dry	yields
T_1	640^{b}	1648^{c}	809^{c}	485^{d}	515^{d}	3098^{d}	1000^{d}	4098^{d}
T_2	1121^{a}	3572^{a}	1509^{a}	1061^{b}	969^{cd}	6202^{a}	2030^{bc}	8232^{a}
T_3	778^{b}	2428^{b}	1092^{c}	734^{c}	1139^{bc}	4298^{bc}	1843^{c}	6171^{bc}
T_4	703^{b}	2156^{b}	1027^{bc}	767^{c}	1248^{bc}	3886^{cd}	2016^{bc}	5902^{c}
T_5	711^{b}	2351^{b}	1217^{b}	1051^{b}	1548^{b}	4279^{bc}	2600^{b}	6879^{b}
T_6	701^{b}	2576^{b}	1588^{a}	1354^{a}	2524^{a}	4864^{b}	3879^{a}	8743^{a}
Significant	*	**	**	**	**	**	**	**
LSD 0.05	264	430	283	198	552	832	604	974
CV (%)	22.58	11.36	15.55	14.42	27.68	12.43	17.94	9.69

Letter(s) within the columns indicate LSD, * = $p \leq 0.05$, ** = $p \leq 0.01$, CV = Coefficient of Variation

the second cutting where DMY ranged from 1,648 to 3,572 kg ha^{-1} for T_1 and T_2, respectively. With the third cutting, DMY ranged from 809 to 1,588 kg ha^{-1} for T_1 and T_6, respectively. Urea treatment significantly increased DMY over control and all rates of CM except the highest rate where dry matter yields of both urea (T_2) and CM (T_6) were similar. For the fourth cutting in the dry season, urea treatment gave significantly greater DMY than control and the first two rates of cattle manure (T_3 and T_4). The highest rate of cattle manure gave significantly greater DMY than the rest. Urea treatment gave a similar DMY to CM at a rate of 12.5 t ha^{-1}. DMY ranged from 485 to 1,354 kg ha^{-1} for T_1 and T_6, respectively. With the fifth cutting, it ranged from 515 to 2,524 kg ha^{-1} for T_1 and T_6, respectively. For this sampling period, urea treatment gave a similar DMY to control, whilst the first three CM rates gave a similar DMY except T_4 where DMY was the lowest. The highest CM rate gave highly significant DMY than the rest. For total DMY in the rainy season, urea treatment gave significantly greater DMY than the rest. All CM rates gave a similar DMY except T_4 where DMY was lowest but significantly greater than control. The results on total DMY in the dry season revealed that total DMY due to urea treatment was similar to all CM treatments except the highest CM rate where the highest rate of CM gave a highly significant DMY over the rest. With total DMY in the rainy season, in all cases, DMY were higher than in the dry season. Urea treatment and the highest rate of CM gave a similar grand total DMY but highly significant over the rest.

Dry matter yields of a three-year sampling period: For the first year DMY, the results showed that the highest CM treatment gave the highest DMY but similar to urea treatment where DMY for both treatments were 8,743 and 8,232 kg ha^{-1}, respectively (Table 3). CM and urea treatments gave significantly DMYs over the control treatment. With the second year DMY, urea and CM treatments gave significantly greater DMY over the control. An increase in CM application rate significantly increased DMYs of the Signal grass. The highest rate of CM gave the highest DMY over urea and the rest. The differences were large and highly significant. For the third year, the results showed that urea treatment gave a similar DMY to the lowest CM treatment but significantly greater than control. DMY of the Signal grass significantly increased with an increase in CM rates where DMY ranged from 7,512 to 14,810 kg ha^{-1} for T_3 and T_6, respectively. The highest rate of CM gave the highest

Table 3: Mean values of dry matter yields from year 1 up to year 3 sampling periods and means of a 3 year grand total dry matter yields (kg ha^{-1}) of Signal grass as influenced by urea and cattle manure application rates

	Years								
Treatments	1st	2nd	3rd	Means of 3 years	Differ from control	Differ from urea	Significant	LSD 0.05	CV (%)
T_1	$4098B^{d}$	$4521B^{f}$	$5117A^{e}$	4578^{e}	-	-3272	*	580	7.32
T_2	$8232A^{a}$	$7724B^{d}$	$7595B^{d}$	7850^{c}	3272	-	**	351	2.59
T_3	6171^{c}	6631^{e}	7512^{d}	6771^{d}	2193	-1079	NS	-	10.52
T_4	$5902B^{c}$	$9095A^{c}$	$8457A^{c}$	7818^{c}	3240	-32	**	655	4.84
T_5	$6879B^{b}$	$11497A^{b}$	$11934A^{b}$	10103^{b}	5525	2253	**	694	3.97
T_6	$8743C^{a}$	$17920A^{a}$	$14810B^{a}$	13824^{a}	9246	5974	**	1555	6.50
Significant	**	**	**	#					
LSD 0.05	974	986	593	490					
CV (%)	10.00	6.84	4.62	7.04					

Superscript letter within the columns indicate LSD of treatments; Capital letter within the rows represent LSD due to seasons, ** = $p \leq 0.01$, CV = Coefficient of Variation; NS = Non-Significant; # Significant levels due to year = **, Treatment = ** and year x treatment=NS. T_1 =control; T_2 = urea @125 kg N ha^{-1} and T_{3-6} = cattle manure @ 3.125, 6.25, 12.5 and 25 t ha^{-1}, respectively

Table 4: Crude Protein (CP) and Neutral Detergent Fibre (NDF) contents of Signal grass in the rainy and dry seasons in the first year sampling period as influenced by urea and cattle manure application rates

	CP	(% DM)				NDF	(% DM)			
	------------	----------				----------	----------			
Treatments	Rain	Dry	Significant	LSD 0.05	CV (%)	Rain	Dry	Significant	LSD 0.05	CV (%)
T_1	$6.77B^{c}$	$8.09A^{cd}$	**	0.15	0.91	76.48	67.38^{ab}	NS	-	14.42
T_2	$7.49B^{ab}$	$13.60A^{a}$	**	1.06	4.47	69.23	67.63^{ab}	NS	-	5.62
T_3	$6.79B^{c}$	$7.76A^{d}$	*	0.60	3.68	72.47	67.09^{ab}	NS	-	4.40
T_4	6.99^{c}	7.73^{d}	NS	-	5.29	73.36A	$69.66B^{a}$	*	2.47	1.54
T_5	$7.10B^{bc}$	$8.65A^{c}$	*	1.08	6.11	71.45	69.94^{a}	NS	-	3.05
T_6	$7.85B^{a}$	$10.79A^{b}$	**	0.67	3.21	72.18A	$65.45B^{b}$	**	1.90	1.22
Significant	**	**				NS	*			
LSD 0.05	0.44	0.76				-	2.99			
CV (%)	4.06	5.60				8.87	2.92			

Superscript letter within the columns indicate LSD of treatments; Capital letter within the rows represent LSD due to seasons, ** = $p \le 0.01$, CV = Coefficient of Variation; NS = Non-Significant; # Significant levels due to year = **, Treatment = ** and year x treatment=NS. T_1 =control; T_2 = urea @125 kg N ha^{-1} and T_{3-6} = cattle manure @ 3.125, 6.25, 12.5 and 25 t ha^{-1}, respectively

Table 5: Acid detergent fibre (ADF) content and dry matter degradability (DMD) at 48 h in cattle rumen of Signal grass in the rainy and dry seasons in the first year sampling period as influenced by urea and cattle manure application rates

	ADF	(% DM)				DMD	(% DM)			
	------------	----------				----------	----------			
Treatments	Rain	Dry	Significant	LSD 0.05	CV (%)	Rain	Dry	Significant	LSD 0.05	CV (%)
T_1	34.94^{ab}	31.95^{b}	NS	-	11.49	73.24^{a}	72.51	NS	-	1.84
T_2	$34.19B^{b}$	$36.20A^{a}$	*	1.35	1.71	69.76^{c}	71.86	NS	-	2.83
T_3	36.19^{a}	37.39^{a}	NS	-	3.45	70.84^{bc}	70.92	NS	-	3.29
T_4	33.88^{b}	37.50^{a}	NS	-	5.64	72.65^{ab}	71.08	NS	-	2.21
T_5	36.21^{a}	36.70^{a}	NS	-	3.68	73.44^{a}	71.07	NS	-	1.79
T_6	36.20^{a}	36.73^{a}	NS	-	5.76	72.84^{a}	72.27	NS	-	3.60
Significant	*	*				**	NS			
LSD 0.05	1.91	3.55				1.95	-			
CV (%)	3.59	6.53				1.79	3.24			

Superscript letter within the columns indicate LSD of treatments; Capital letter within the rows represent LSD due to seasons, ** = $p \le 0.01$, CV = Coefficient of Variation; NS = Non-Significant; # Significant levels due to year = **, Treatment = ** and year x treatment=NS. T_1 =control; T_2 = urea @125 kg N ha^{-1} and T_{3-6} = cattle manure @ 3.125, 6.25, 12.5 and 25 t ha^{-1}, respectively

DMY. The differences were large and highly significant. With the three-year average on DMY, urea and manure treatments gave highly significant effect over control. An increase in CM rate highly increased DMY of the Signal grass. Urea treatment gave a similar DMY to cattle manure rate of 3.125 tonnes ha^{-1} (T_3). An increase in CM rate significantly increased DMY of the Signal grass. When compared DMY between control (T_1) and the rest, it gave the margin increases of 3,272, 2,193, 3,240, 5,525 and 9,246 kg ha^{-1} for T_2 up to T_6, respectively. Whist the differences between urea and the rest were –3272 kg ha^{-1} for control and -1,079; -32; 2,253 and 5,974 kg ha^{-1} for T_3 up to T_6, respectively. The highest rate of cattle manure gave the highest margin increases in dry matter yield over the urea treatment.

Forage quality: With CP in the rainy season, the results showed that the CP contents of the first two rates of CM were similar to control, whilst the other higher rates of CM (T_5 and T_6) and urea gave significantly greater CP contents than control. Urea treatment gave a similar CP content to the highest rate of CM treatment where the values were 6.77 and 7.85%, respectively (Table 4). For the dry season, CP content of the urea treatment was the highest followed by T_6, whilst the rest were similar. Urea gave a highly significant effect on CP content than the rest where the values were ranging from 7.73 to 13.60% for T_4 and T_2, respectively. In all cases, CP contents were higher for the dry season than the rainy season. CP contents for the rainy season ranged from 6.77 to 7.85% for T_1 and T_6, respectively. Whilst in the dry season, it ranged from 7.73 to 13.60% for T_4 and T_2, respectively. NDF contents in all treatments for the rainy season did not show any significant differences with the values ranged from 69.23 to 76.48% for urea and control, respectively. However, NDF contents found within the dry season, in most cases, were similar although the highest CM rate was the lowest. NDF contents in the dry season, in most cases, were lower than the rainy season except T_2 and T_3 where the values were slightly higher.

In the rainy season, the lowest ADF content (33.88%) was obtained from CM at the application rate of 6.25 t ha^{-1} and did not significantly differ from control and urea treatments (Table 5). For the dry season, the lowest ADF content (31.95%) was found with control but significantly different from other treatments. Apart from control, ADF contents in all treatments did not significantly different from one another. ADF content in each treatment was similar in both seasons except for the urea treatment in the rainy season where it gave significantly lower ADF content than the dry season. For the rainy season, CM at a rate of 12.5 t ha^{-1} gave the highest DMD but did not significantly different from control, CM at the rates of 6.25 and 25 t ha^{-1}. There was no significant difference due to treatment on DMD found in the dry season and also between seasons on DMY.

DISCUSSION

The amount of rainfall of the 4-year experimental period showed that there was an adequate amount of rainfall for growth of the Signal grass particularly in the rainy season. The highest amount of rainfall was attained in the 2000 (1,783.8 mm), while a 5-year average of the total amount of rainfall from 1993 to 1997 was only 1,164.2 mm. The results indicate an unusual amount of rainfall in the region in the 2000. Soil conditions of Korat soil series (Oxic Paleustults) could be comparable to Yasothon soil series (Oxic Paleustults) in terms of soil fertility and soil structure where both soils are found in the northeastern region of Thailand. The initial soil analysis data revealed that Korat soil series is a poor soil type since it indicated low levels of soil pH, organic matter and macronutrients particularly Nitrogen (N), Phosphorus (P) and Potassium (K). Mean soil NPK values were almost at critical levels for crop growth[19]. The poor soil fertility has been reported[4,5,20]. Thus, Korat soil series is a poor soil type in the region. The poor fertility of Korat soil series can cause a severe problem for growers to achieve high crop yields. Soil analysis data at the third cutting for the first year samplings showed that soil pH was relatively low indicated an acidic range (5.45-5.85) for plant growth[4,21]. The poor fertility level of this soil series could be attributable to the previous history of crop cultivation and partly to a high annual leaching rate of soil nutrients[21,22]. Shelton *et al.*[19] reported that Korat soil series normally contained approximately 1 ppm of nitrate N, 10 ppm of P and 70 ppm of K. Thus to achieve high crop yield in each cropping session, this soil series may require a large amount of chemical fertilisers (NPK) apart from soil amendment materials. This is to sustain a high level of soil OM for subsequent cropping sessions. However, the increment of OM in most soils in the tropics after being used by many other annual crops for a certain period of time could be relatively low due to high environmental temperatures hasten decomposition rate where it took place by soil microorganisms[6,23].

The results on DMY of the Signal grass for the first year cuttings in the rainy season revealed that urea at a rate of 125 kg N ha^{-1} gave a highly significant effect on DMY over the control and the first three rates of CM. The results suggested that nitrogen derived from urea tremendously promoted the growth of the Signal grass since nitrogen in the Korat soil series could have been inadequately available. This result confirms the study of Shelton *et al.*[19]. Thus a large amount of urea application should be required for high crop yields. The highest rate of CM (25 t ha^{-1}) and urea gave the highest DMY but both were similar particularly at the third cutting. The results suggested that the highest rate of CM was able to provide adequate amount of nutrients particularly nitrogen for the Signal grass where it gave DMY comparable to urea treatment. Soil analysis data at the third cutting indicated that the highest CM rate gave significantly higher soil N, P and particularly soil K than the urea treatment where the amounts of P and K for the urea treatment were only 15.25 and 13.00 ppm, respectively. These values of both P and K could be at a critical level for crop growth as reported by Shelton *et al.*[19]. Magdoff and Amandon[24] confirm this finding. However, they used ammonium nitrate instead of urea, they stated that N application in the form of ammonium nitrate generally lowering soil pH, decreased extractable P, K, Ca and Mg while manure application increased OM, P, Ca and K but not Mg. For this work, soil analysis indicated that the plots received CM contained much higher organic matter than urea. It has been advocated that OM, in general, has a high cation exchange capacity and improves water-holding capacity and also the capacity to produce chelate cations[4,21,25]. Crop productivity could be increased through the mineralisation of plant materials in soils providing adequate nutrient supply during the period of organic decomposition[21,26]. The result indicated that CM requires a certain period of time for further decomposition for the release of nutrients and to improve soil property for high DMY. The highest CM rate gave the highest DMY in the dry season. This could be attributable to the large amount of CM added to the soil where it improved water-holding capacity and slowly releases of soil nutrients particularly N. However, DMY of the Signal grass in the dry season, in all cases, were much lower than in the rainy season. This could be partly due to drought conditions where soil moisture content could have been relatively low, thus a stunted growth of the Signal grass was occurred. Total DMY in the rainy season was significantly higher for urea treatment than the rest. The results suggested that the highest CM rate was not able to provide adequate amount of N for the Signal grass compared with the urea treatment due to the slow release of nutrients from the organic materials of CM. Nevertheless, total DMY at the highest rate of CM in the dry season (the 4th and 5th cuttings) were significantly higher than the rest. The ratios on DMY between urea (T_2) and the highest CM rate (T_6) in the rainy and dry season were: for T_2 = 6,202/2,030 = 3.05 and for T_6 = 4,864/3,879 = 1.25 (Table 2). These figures provide a clearer effect of CM on the distribution of DMY where CM gave much better distribution of DMY than the urea treatment throughout the year. The results also indicated a highly significant effect of urea and the highest rate of CM on the grand total DMY. The highest rate of CM gave higher DMY than urea but both were not statistically different from each other. Therefore, to achieve high DMY of the Signal grass, a high amount of CM equivalent to T_6 is required for Korat soil series.

In comparing DMY among the 3-year sampling periods, the results showed that urea treatment gave a decline in DMY significantly with time. The decline in DMY for urea treatment could have been partly attributed to the depletion of soil nitrogen being taken up by the Signal grass and the loss of nitrogen through leaching where an annual N loss could possibly range from 50-80 kg ha^{-1}[21]. The other reason could have been due to the utilisation of N by microorganisms where the microbes decomposed soil OM rapidly with time resulting in the compaction of soil particles, hence slowly decreasing soil pore-spaces for aeration and water-holding capacity[22]. CM application significantly increased DMY in the subsequent years, thus DMY of years 2 and 3 were significantly higher than year 1. This could be partly attributable to the addition amounts of CM in the soil released more nutrients particularly N for the higher DMY of the Signal grass in the subsequent years and partly to an improvement of soil structure. The lowest CM application rate had no significantly effect on DMY in the subsequent years. This may have been due to a small amount of CM being added where the amount was insufficient to provide plentiful amount of N and other nutrients for the Signal grass. The mean values of the 3-year period on DMY significantly increased with an increase in CM application rates. These results were similar to the work reported by Sukasame *et al.*[27] with *Brachiaria humidicola*. They found that CM at the application rates of 0, 12.5, 25 and 37.5 t ha^{-1} significantly increased DMY up to a rate of 25 t ha^{-1} only with the DMY of 6,350, 8,931, 12,425 and 11,894 kg ha^{-1}, respectively. Of the 3-year average, the differences in DMY between urea and control, urea and CM application rates of 3.125 and 6.25 kg ha^{-1} were -3,272, -1,079 and -32 kg ha^{-1}, respectively. A positive result was found between urea and CM at the higher rates of 12.5 and 25 t ha^{-1} where both gave positive DMY of 2,253 and 5,974 kg ha^{-1}, respectively. The results revealed that CM at a rate of 12.50 t ha^{-1} and a higher rate gave better DMY of the Signal grass than the urea treatment. A highly significant effect due to year and treatment on DMY was found but there was no significant interaction between year x treatment. Therefore, for Korat soil series, a minimum application rate of CM for Signal grass production should not be lesser than 12.5 t ha^{-1}.

With forage quality in the rainy season, CP content was highest with the highest rate of CM. However, there was no significant difference between urea and the highest rate of CM. CM at the application rates of 12.5 and 25 t ha^{-1} significantly increased CP content from 7.10 to 7.85%, respectively. This result was similar to the study of Sukkasame *et al.*[26]. They worked with *B. humidicola* grass with the same rates of CM. They stated that these CM application rates significantly increased CP content from 5.00 to 6.52%. The results suggested that soil N derived from both CM rates could significantly increase CP content in most of the grasslands. This finding confirms the study of Chapman and Kretschmer[28], whilst other treatments were not able to supply adequate amounts of N to increase high CP contents. It was found that CP contents in most of the treatments in the dry season were significantly higher than in the rainy season. However, the pattern on CP contents due to treatments in the dry season was similar to the rainy season. The high CP contents of the same treatment found in the dry season greater than the rainy season could be attributable to the effect due to the amounts of rainfall (72 mm in March and 164 mm in April) where rainwater aided the re-growth of the Signal grass. Thus the Signal grass started to produce more young leaves resulting in the higher level of CP% in the dry season than the rainy season.

NDF contents found in the rainy season were similar in all treatments but for the dry season NDF contents were significantly affected by the treatments where the highest rate of CM attained the lowest NDF content. The result suggested that the highest rate of CM produced the utmost forage quality perhaps due to the high amounts of nutrients particularly N. ADF contents in the rainy season were similar in all treatments except urea and the 6.25 t ha^{-1} of CM where they attained lower ADF contents than the rest. Most of NDF and ADF contents of the same treatment in the dry and rainy seasons were not significant different from each other except the urea treatment where the urea treatment in the rainy season gave lower ADF than in the dry season. Chinosaeng *et al.*[29] reported that different application rates of CM did not significantly affect NDF and ADF of Setaria grass (*Setaria sphacelata*). The results on NDF found in the rainy season and ADF in the dry season agree with the work of Chinosaeng *et al.*[28]. A number of workers reported that NDF and ADF contents of the above ground tissue of the Signal grass were 67.03±3.03 and 40.33±2.93% (60 days cutting interval)[30]; 68.50 and 36.76%[31] and 74.6 and 39.9% [32] respectively. With the cutting ages of 45, 60 and 75 days after emergence the Signal grass gave NDF contents of 63.2, 67.8 and 69.6% and ADF contents of 39.4, 41.4 and 43.8%, respectively[33]. NDF contents found with this study were ranging from

69.23 to 76.48% in the rainy season and from 65.45 to 69.94% in the dry season. ADF contents were ranging from 33.88 to 36.21% in the rainy season and from 31.95 to 37.50% in the dry season. DMD in the rainy season were similar for all treatments except urea and the first two application rates of CM treatments where the DMD were lower than the rest. The differences due to treatments on DMD were highly significant in the rainy season while there was no significant effect due to treatments found on DMD in the dry season. DMD of the same treatment in the rainy and dry seasons were not significantly different from each other.

The results on the *in vivo* digestibility (DDM) with *B. decumbens* cv. Basilisk in Australia revealed that the plants of 6 weeks' re-growth fed to sheep in Southeast Queensland gave 64% DDM[34]. Whilst with the whole plants of the same grass being cut at every 4 and 12 weeks and fed to buffaloes in Northeast Thailand gave 74 and 62% DDM, respectively[35]. With the result of the same grass on the *in vivo* nylon bag at 48 h being cut at the ages of 45, 60 and 75 days, it gave the figures of 71.8±9.96, 66.5±6.40 and 58.3±7.67%, respectively[33]. For this study, DMD in the rainy season ranged from 67.41 to 73.44% and in the dry season from 70.92 to 77.62%. The results indicated the younger the cutting age the higher the digestibility.

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