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Dry Matter Yields and Forage Quality of Grass Alone and Grass Plus Legume Mixture in Relation to Cattle Manure Rates and Production Methods

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ABSTRACT

This work was carried out at Khon Kaen University from April-November 2011 to determine dry matter yields and forage quality of the Purple Guinea grass (*Panicum maximum* cv. TD 58) and grass plus legumes grown on Korat soil series (Oxic Paleustults). The 3 Production Methods (PM) were used viz., without legume (PM1), with Verano stylo, *Stylosanthes hamata* cv., Verano, (PM2) and with Wynn cassia, *Chamaecrista rotundifolia* cv., Wynn, (PM3). Dry Cattle Manure (CM) rates of 0, 8, 16 and 24 t ha^{-1} were used. They were subjected to a 3×4 factorial arranged in a Randomized Complete Block Design (RCBD) with 4 replications. The results showed that an increase in cattle manure rates highly increased both Dry Matter Yields (DMY%) of the grass alone and grass plus legumes. The high DMY of 10,596 and 10,673 tons ha^{-1} were attained with the PM2 and the PM3, respectively. An increase in cattle manure rates highly decreased Crude Protein (CP%) of the grass alone and grass plus legumes mixture. Neutral Detergent Fiber (NDF%) for the grass alone increased with an increase in cattle manure rates only up to 8 t ha^{-1} but the production methods did not. The NDF% of the grass plus legumes mixture highly increased with an increase in cattle manure rates but a reverse result was found with the production methods. Acid Detergent Fiber (ADF%) for the grass alone highly increased but the increase was only up to 8 t ha^{-1}. Production methods had no significant effect on the ADF%. An increase in cattle manure rates did not significantly affect DMD%, except that of the production methods where an increase was with the PM2 only.

Key words: Purple guinea grass, legumes, cattle manure, crude protein, dry matter degradability

INTRODUCTION

It is well established that farmers normally use chemical fertilizers to increase Dry Matter Yields (DMY) of forage for livestock production. In particular, DMY of grasses could be increased enormously by nitrogen fertilizer (N) where Chen *et al*. (1981) attained their highest yield with the use of N up to 300 kg N ha^{-1} $year^{-1}$. However, DMY and forage quality may not remain at a high stability with the continued applying of chemical fertilizer to the soil, e.g., a decrease in DMY can occur when chemical fertilizers containing NH_4^+ is added to the soil resulting in an increase in soil acidity due to the NH_4^+. The NH_4^+ in soil may be oxidized to NO_3^- and H^+ by soil bacteria (Miller and Donahue, 1990; Teitzel *et al.*, 1991; Barak *et al.*, 1997; Suksri, 1999) and a process on “Gassing off” can also occur. The high application rate of nitrogen chemical fertilizers on pasturelands in Western Europe has sometimes resulted in the release of N_2O and NH_3 gases into the atmosphere (Mannetje, 2003). In Thailand, the use of chemical fertilizers, especially urea has been increased, e.g., in the 2013 alone an amount of 1.9 billion Baht was spent on urea (Anonymous, 2013). It is a common practice that the more the use of the chemical fertilizers for agricultural production the more the increase in the environmental hazards as well as the high cost of investment. In Sweden, it was reported that organic methods gave a long-term sustainability on livestock production where organic food supplies have been increased, e.g., in the 1998 alone organic milk and dairy products increased by 3% (Cederberg and Mattsson, 2000). Organic milk products in the European countries increased continuously with time, particularly in Sweden, Denmark, Switzerland and Austria where the percentages increased were 4.3, 7, 10 and 15, respectively (Rosati and Aumaitre, 2004). It was reported that eco-methods for conservation play an important role in the European countries, e.g., species diversity is commonly recognized as a task for organic agriculture in many European countries (Van Elsen, 2000). Small ruminant livestock farming amongst the Mediterranean countries such as sheep farming had used organic methods for the increases in its sustainability compared with the inorganic farming (Ronchi and Nardone, 2003). Some published data in Thailand revealed that rotating grazing by beef cattle on organic grassland increased biological diversity with a long lasting stability of pastureland and its maintenance (Phonbumrung and Watanasak, 2007). Therefore, it may be of a tangible value to carry out more experiments concerning the use of animal manure together with the use of natural nitrogen derived from nitrogen fixing bacteria in roots of the leguminous crops in place of nitrogen chemical fertilizers. It has been reported that grass and legume mixtures provided better soil properties than the application of nitrogen fertilizer alone and it was found that residual effects derived from root nodules remain in soil for a long period of time (Partridge and Wright, 1992; Jones and Jones, 2003). The application of organic materials to the soil has also been reported by Celik *et al*. (2004), Pholsen *et al*. (2005, 2014a) and Hatch *et al*. (2007) where they found the compaction of soils with the application of organic fertilization was lesser than that of the inorganic fertilizer applications. The use of organic materials in pasturelands where grass and legumes are allowed to grow together could improve soil properties, increase nutritive value of fodders or silages for animals and also the forage yields can be enormously increased (Ng and Wong, 1976; Bamikole *et al*., 2001; Ahmed *et al*., 2012). Organic grasslands have shown a huge potential in increasing animal growth rates and animal production (Bamikole *et al*., 2001; Trevor and Albrecht, 2004).

Therefore, in order to keep pace with the rapid expansion of many products derived from organic agriculture and able to meet the high demand of the markets, farmers in Thailand should pay more attention to practice organic farming systems for their pasturelands rather than only applying chemical fertilizers alone.

The objectives of this research work include how the purple Guinea grass plants responded to 2 species of legume crops when grow together and also 4 rate of cattle manure application on both forage yield and forage quality. To be more precise, it is of a tangible value to determine the effects due to both cattle manure application rates and the production methods used.

MATERIALS AND METHODS

This work was conducted at the Experimental Farm, Khon Kaen University, Khon Kaen, Thailand from 2009-2011 where the work was carried out for more than a 3 year period and only the results of the third year (April-November 2011) are included in this study. The experiment was laid out in a 3×4 factorial arranged in a Randomized Complete Block Design (RCBD) with 4 replications. Purple Guinea grass (*Panicum maximum* cv., TD 58) was used alone and together with 2 legume species under 3 Production Methods (PM), i.e., PM1 IS grass alone, PM2 IS grass with Verano stylo (*Stylosanthes hamata* cv., Verano) and PM3 IS grass with Wynn cassia (*Chamaecrista rotundifolia* cv., Wynn). The 4 Cattle Manure (CM) rates (0, 8, 16 and 24 t ha^{-1}) were used in each production method. Thus there were 12 treatment combinations with 48 plots altogether and each plot has a dimension of 4.5×4.5 m in width and length, respectively with a walking path in between the plots of 75 cm. The land area being used was a 1,600 m^2 of a Korat soil series (Oxic Paleustults). The land area was ploughed twice and harrowing once. Soil samples of this third year experimental period were initially taken from each plot to the depth of approximately 25 cm and they were used for soil analysis on soil properties. Root stocks of the Purple Guinea grass were planted into rows by hand at distances between rows and within rows of 75×75 cm, respectively. Legume seeds at a rate of 10 kg ha^{-1} were sown into the soil in between the grass rows. Each cattle manure sample was divided into 2 equal portions. The first half was applied by hand on the 30th of May 2011 and the second half was applied on the 7th of August 2011. A quadrat with a dimension of 0.75×0.75 m in width and length was used in each sample for plant dry weight determinations. The plants were cut off at 10 cm above ground level and 4 quadratic areas of the plants were randomly cut out from each plot. For the third year cuttings, DMY were carried out 7 times in the rainy season (every 28 days) and once again in the dry season. The plant samples were oven dried at 60°C for 72 h and then weighed out for DMY. A portion of each dry matter sample from each replication was ground to pass through a 1 mm sieve screen and then kept separately in plastic bags for plant tissue analysis. The DMY obtained in the dry season was not included in the plant tissue analysis due to its small quantity. Chemical component analysis of the rainy season samples was carried out for Crude Protein (CP) by Kjeldahl method (AOAC., 1990), Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) using the method of Van Soest *et al*. (1991). Dry Matter Degradability (DMD) analysis was carried out with the nylon bag technique (Orskov *et al*., 1980). The quality of grass plus legume was calculated by the formula described by Nakamanee *et al*. (2004) as follow:

$$\text{Quality (\%)} = \frac{(\text{Quality of grass (\%)} \times \text{DMY of grass}) + (\text{Quality of legume (\%)} \times \text{DMY of legume})}{\text{DMY of grass+DMY of legume}}$$

The obtained data were statistically calculated where appropriate using a SAS computer program (SAS., 1998).

RESULTS

Meteorological data and soil properties: With monthly rainfalls, it was found that monthly rainfalls ranged from 10.2-355.6 mm for the months of November and September, respectively with a total amount of rainfalls up to 1,433.9 mm (within 103 days of rainfalls) throughout the experimental period (Table 1). Mean values of minimum and maximum temperatures were 23.60 and 32.50°C, respectively with an average value of 28°C and average value of relative humidity of 91%. For dry cattle manure analysis data, it was found that mean values of pH, OM, total N, total P and total K of 9.16, 43.16, 1.47, 1.07 and 3.84%, respectively.

Initial and final soil properties: Soil analysis data of the third year experimental period for the PM1 revealed that initial mean values of soil pH, OM, total N, extractable P and exchangeable K were 4.92, 0.86 and 0.039%, 7.5 and 85 ppm, respectively (Table 2), for the PM2 with the values of 4.96, 0.81 and 0.043%, 7.0 and 133.5 ppm, respectively and for the PM3 with the values of 5.17, 0.85 and 0.042%, 8.0 and 155.5 ppm, respectively. Soil analysis data due to the cattle manure applications on their ranges of soil pH, OM, total N, extractable P and exchangeable K were 4.53-5.44 for 0 and 24 t ha^{-1}, 0.80-0.87% for 8 and 0 t ha^{-1}, 0.039-0.042% for 0 and 24 t ha^{-1}, 3.7 to 13.3 ppm for 0 and 24 t ha^{-1} and 68.7-221.7 ppm for 0 and 24 t ha^{-1}, respectively.

For the final soil analysis data, the results showed that mean values of soil pH, OM, total N, extractable P, exchangeable K were 5.30, 0.99 and 0.061%, 7.4 and 219.0 ppm for the PM1, 5.29, 1.02 and 0.054%, 7.4 and 190.6 ppm for the PM2 and 5.45, 1.05 and 0.061%, 7.6 and 199.6 ppm for the PM3, respectively. With the applications of cattle manure, the ranges of soil pH, OM, total N, extractable P and exchangeable K were 4.91-6.13 for 0 and 24 t ha^{-1}, 0.99-1.05% for 16 and 24 t ha^{-1}, 0.056-0.063% for 16 and 24 t ha^{-1}, 2.7-16.5 ppm for 0 and 24 t ha^{-1} and 34.2-371.5 ppm for 0 and 24 t ha^{-1}, respectively.

Dry matter yields of grass alone, grass plus legume and weeds: The results on dry matter yields showed that an increase in cattle manure rates significantly increased grass dry matter yields with mean values ranged from 931-10,153 kg ha^{-1} for cattle manure rates of 0 and 24 t ha^{-1}, respectively. The differences were large and highly significant (Table 3). The grass dry matter yield due to the effect of production methods was also large with values ranged from

Table 1: Monthly rainfalls (mm), numbers of days with rainfall, daily temperatures and relative humidity from May to November 2011 recorded at the experimental Farm, Khon Kaen University (Anonymous, 2011)

	Rainfalls		Temperatures (°C)			
Months	Amount	Days	Minimum	Maximum	Average	Relative humidity (%)
May	98.3	11	24.2	34.4	29.3	90
June	209.5	13	24.9	33.6	29.3	87
July	314.0	17	24.2	33.1	28.7	91
August	236.9	21	23.8	31.7	27.8	93
September	355.6	23	24.1	31.6	27.9	95
October	209.4	16	23.0	31.1	27.1	90
November	10.2	2	20.7	31.9	26.3	89
Total	1433.9	103				
Average	204.8	15	23.6	32.5	28.0	91

Table 2: Soil analysis data of the initial and final sampling periods as influenced by both cattle manure rates and production methods

	Production methods (PM)			Cattle manure rates (CM, t ha^{-1})			
Items	PM1	PM2	PM3	0	8	16	24
Initial							
pH (1:2.5)	4.92	4.96	5.17	4.53	4.82	5.26	5.44
OM (%)	0.86	0.81	0.85	0.87	0.80	0.86	0.83
Total N (%)	0.039	0.043	0.042	0.039	0.042	0.040	0.042
Extrt. P (ppm)	7.5	7.0	8.0	3.7	5.3	7.7	13.3
Exch. K (ppm)	85.0	133.5	155.5	68.7	90.0	118.3	221.7
Final							
pH (1:2.5)	5.30	5.29	5.45	4.91	4.85	5.48	6.13
OM (%)	0.99	1.02	1.05	1.01	1.02	0.99	1.05
Total N (%)	0.061	0.054	0.061	0.058	0.058	0.056	0.063
Extrt. P (ppm)	7.4	7.4	7.6	2.7	3.9	6.8	16.5
Exch. K (ppm)	219.0	190.6	199.6	34.2	136.9	269.7	371.5

OM: Organic matter, Extrt. P: Extractable phosphorus, Exch. K: Exchangeable potassium, N: Nitrogen

Table 3: Dry matter yields (kg ha^{-1}) of grass alone, grass+legume and weeds as influenced by cattle manure rates and production methods, grown on Korat soil series at Khon Kaen University Farm, Khon Kaen, Thailand

	Cattle manure rates (t ha^{-1})				
Production methods	0	8	16	24	Mean
Grass					
PM1	609	4658	5512	9436	5054^{B}
PM2	1363	5286	5639	10499	5697^{AB}
PM3	820	5880	8138	10525	6341^{A}
Mean	931^{D}	5275^{C}	6430^{B}	10153^{A}	
Grass+legume					
PM1	609	4658	5512	9436	5054^{b}
PM2	3537	7614	6755	10596	7125^{a}
PM3	4415	7538	8768	10673	7849^{a}
Mean	2853^{c}	6603^{b}	7012^{b}	10235^{a}	
Weeds					
PM1	3467	4277	3863	3085	3673^{x}
PM2	943	2690	1664	2186	1871^{y}
PM3	605	1923	1910	2415	1714^{y}
Mean	1672^{y}	2963^{x}	2479^{x}	2562^{x}	
	Significant levels				
	PM	CM	PM×CM	CV (%)	SEM (±)
Grass	**	**	ns	19.47	554.56
Grass+legume	**	**	ns	17.42	581.41
Weed	**	**	*	25.39	307.11

Letter(s) in each row and in the final column of means indicated least significant differences of the Duncan's Multiple Range Test (DMRT) at probabilities (p) of **0.01 and *0.05, CV %: Covariant percentages, SEM: Standard errors of means, ns: Non significant, CM: Cattle manure, PM: Production method

5,054-6,341 kg ha^{-1} for the PM1 and the PM3, respectively. However, the PM1 was similar to the PM2 and the PM2 was similar to the PM3 yet the differences between the PM1 and the PM3 were large and highly significant. With grass plus legume, the results showed that an increase in cattle manure rates significantly increased dry matter yields yet an increase in the cattle manure rate of 16 t ha^{-1} did not differ from the 8 t ha^{-1}. Nevertheless, at the highest rate (24 t ha^{-1}) of dry matter yields were significantly higher than the rest with values ranged from 2,853-10,235 kg ha^{-1} for 0 and 24 t ha^{-1}, respectively. The difference was large and highly significant. With the effects due to the production methods, the results showed that the PM2 was significantly higher than the PM1 but the PM3 was similar to the PM2 with values ranged from 5.054-7.849 kg ha^{-1}, respectively. The differences were large and highly significant. For weeds, an increase in cattle manure rates significantly increased weed dry matter yields but the increase was only up to 8 t ha^{-1}. Further increases did not increase weed dry matter yields with values ranged from 1,672-2,963 kg ha^{-1} for 0 and 8 t ha^{-1}, respectively. The differences were large and highly significant. For the interaction between production methods and cattle manure rates, the results revealed that there was no effect due to both production methods and cattle manure rates but significantly found with that of the weeds dry matter yields.

Forage quality of grass alone: The results on Crude Protein (CP) showed that an increase in cattle manure rates significantly decreased the CP from 0 up to 8 t ha^{-1} only. Further increases in the cattle manure rates gave a similar level as that of the 8 t ha^{-1} with the values ranged from 9.21-10.16% for 24 and 0 t ha^{-1}, respectively. The differences were large and highly significant (Table 4). For the production methods, the results indicated that the PM2 gave significantly higher CP than the PM1 but the PM2 was similar to the PM3 with the values ranged from 9.21-9.81% for the PM1 and the PM3, respectively. The differences were large and highly significant. A statistical significant interaction between the PM×CM was also found. With Neutral Detergent Fiber (NDF), an increase in the cattle manure rates significantly increased the NDF up to 8 t ha^{-1} only. Further increases did not significantly increase the NDF of the forage with the values ranged from 72.93-74.46% for 0 and 16 t ha^{-1}, respectively. The differences were large and highly significant. For the NDF on the PM, PM did not affect the NDF%. There was no interaction between cattle manure rates and production methods found on the NDF. With Acid Detergent Fiber (ADF), an increase in cattle manure rates significantly increased the ADF up to 8 t ha^{-1} only. Further increases did not significantly increase the ADF% with values ranged from 40.19-43.04 for 0 and 24 t ha^{-1}, respectively. The differences were large and highly significant. For the production methods, the results showed that there was no significant effect due to the production methods with values ranged from 41.65-42.33% for the PM1 and PM2, respectively. Similarly, there was no significant interaction effect due to the PM×CM. For Dry Matter Degradability (DMD), an increase in cattle manure rates did not increase the DMD of the forage. A similar result was found with both the production methods used and the PM×CM, i.e., no significant effect on the DMD was found.

Forage quality of grass plus legume mixture: The results on the effect due to cattle manure application rates on forage

Table 4: Forage quality of the grass alone, grown on Korat soil series (Oxic Paleustults) in the rainy season as influenced by cattle manure rates and production methods

	Cattle manure rates (t ha^{-1})				
Production methods	0	8	16	24	Mean
CP (%)					
PM1	8.96	9.54	9.27	9.08	9.21^{B}
PM2	10.85	9.57	9.37	9.43	9.81^{A}
PM3	10.67	10.19	9.28	9.10	9.81^{A}
Mean	10.16^{a}	9.77^{ab}	9.31^{b}	9.21^{b}	
NDF (%)					
PM1	72.90	74.43	74.41	73.92	73.91
PM2	73.52	74.68	74.26	74.58	74.26
PM3	72.39	73.96	74.72	74.34	73.85
Mean	72.93^{b}	74.36^{a}	74.46^{a}	74.28^{a}	
ADF (%)					
PM1	39.71	42.13	41.99	42.76	41.65
PM2	41.44	42.76	42.52	43.07	42.33
PM3	39.87	42.28	43.11	43.28	42.14
Mean	40.19^{b}	42.39^{a}	42.54^{a}	43.04^{a}	
DMD (%)					
PM1	69.91	72.17	72.10	72.81	71.74
PM2	73.40	72.32	72.42	71.05	72.29
PM3	72.30	70.86	71.74	71.47	71.59
Mean	71.87	71.78	72.08	71.77	

	Significant levels				
	PM	CM	PM×CM	CV (%)	SEM (±)
CP	**	**	*	6.72	0.323
NDF	ns	**	ns	1.22	0.450
ADF	ns	**	ns	1.96	0.412
DMD	ns	ns	ns	2.70	0.971

Letter(s) in each row and in the final column of means indicated least significant differences of the Duncan's Multiple Range Test (DMRT) at probabilities (p) of **0.01 and *0.05, CV%: Covariant percentages, SEM: Standard errors of means, ns: Non significant, PM: Production method, CM: Cattle manure, CP: Crude protein, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, DMD: Dry matter degradability

quality of grass plus legume showed that an increase in cattle manure rates significantly decreased Crude Protein (CP) in the tissues of the grass and legume mixture. The decrease was persistently found and highly significant throughout the experimental period. The crude protein values ranged from 9.24-12.03% for 24 and 0 t ha^{-1}, respectively (Table 5). With the production methods, it was found that the PM1 was the lowest followed by the PM2 and the highest was with the PM3 with values ranged from 9.21-11.22%, respectively. The differences were large and highly significant. With an interaction between the PM×CM, it was found that there was a highly significant effect due to the PM×CM interaction. For Neutral Detergent Fiber (NDF), a reverse result from that of the CP was found with the NDF where an increase in the cattle manure rates significantly increased the NDF% with values ranged from 63.74-74.08% for 0 and 24 t ha^{-1}, respectively. The differences were large and highly significant. With the production methods, the results revealed that the PM3 attained the lowest followed by the PM2 and highest with the PM1 with values ranged from 66.85-73.79% for the PM3 and PM1, respectively. The differences were large and highly significant. It was also found that the PM×CM interaction on the NDF% was highly significant. With Acid Detergent Fiber (ADF), an increase in cattle manure rates significantly increased the ADF% with values ranged from 39.07-43.03% for 0 and 24 t ha^{-1}, respectively. The differences were large and highly significant. For the Production Methods (PM), there was no significant effect due to the production methods. There was a highly significant effect due to the PM×CM on the ADF%. With Dry Matter Degradability (DMD), the results showed that an increase in cattle manure rates did not increase the DMD% yet with the production methods the DMD% of the PM2 was significantly higher than the PM1. However, the PM1 was similar to the PM3 hence the PM2 may be considered as the best method to be chosen with values ranged from 71.74-74.26% for the PM1 and PM2, respectively. The differences were large and highly significant. A highly significant effect was found with an interaction between the PM×CM.

DISCUSSION

For the third year experimental period carried out from May to November 2011 at Khon Kaen University, the results showed that amounts of rainfalls were adequately received in all months of the experimental period with the amount of rainfalls up to 1433.9 mm indicating that soil moisture contents were adequately available hence no drought condition was taken place. Mean values of the relative humidity, minimum and maximum temperatures were 91%,

Table 5: Forage quality of grass plus legume in rainy season as influenced by production methods and cattle manure rates

	Cattle manure rates (t ha^{-1})				
Production methods	0	8	16	24	Mean
CP (%)					
PM1	8.96	9.54	9.27	9.08	9.21^{C}
PM2	12.54	11.06	10.13	9.48	10.80^{B}
PM3	14.60	11.38	9.74	9.17	11.22^{A}
Means	12.03^{a}	10.60^{b}	9.72^{c}	9.24^{d}	
NDF (%)					
PM1	72.90	74.43	74.41	73.92	73.91^{A}
PM2	66.29	71.44	72.37	74.83	70.40^{B}
PM3	52.02	68.41	72.89	74.05	66.85^{C}
Means	63.74^{d}	71.43^{c}	73.22^{b}	74.08^{a}	
ADF (%)					
PM1	39.71	42.13	41.99	42.76	41.65
PM2	40.08	41.84	41.70	43.39	41.38
PM3	37.42	41.38	42.79	43.21	41.20
Means	39.07^{c}	41.78^{b}	42.16^{b}	43.03^{a}	
DMD (%)					
PM1	69.91	72.17	72.10	72.81	71.74^{B}
PM2	77.57	74.88	73.76	70.85	74.26^{A}
PM3	72.74	71.63	72.18	71.53	72.02^{B}
Means	73.40	72.89	72.68	71.73	

	Significant levels				
	PM	CM	PM×CM	CV (%)	SEM (±)
CP	**	**	**	5.10	0.265
NDF	**	**	**	1.71	0.603
ADF	ns	**	**	1.58	0.326
DMD	**	ns	**	2.35	0.854

Letter(s) in each row and in the final column of means indicated least significant differences of the Duncan's Multiple Range Test (DMRT) at probabilities (p) of **0.01 and *0.05, CV%: Covariant percentages, SEM: Standard errors of means, ns: Non significant, PM: Production method, CM: Cattle manure, CP: Crude protein, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, DMD: Dry matter degradability

23.6 and 32.5°C, respectively. This climatic condition may be considered as the most suitable environment for the growth of the grass and legume crops (Anonymous, 2011). Cook *et al*. (2005) reported that Guinea grass plants grew well with an annual rainfall above 1,000, 1000-2000 mm for Verano stylo, 900-1500 mm for Wynn Cassia. It was found that mean values of minimum and maximum temperatures were 20.7 and 34.4°C, respectively with a mean value of a relative humidity of 91%. This condition should have favored the growth of the Purple Guinea grass and the legume crop plants. Whiteman (1980) reported that tropical grasses and legume crops show maximum growth at different temperatures ranged from 35-45°C for grasses and 30°C for legumes.

The results on cattle manure analysis for mean values of pH, Organic Matter (OM), total nitrogen (N), total phosphorus (P) and total potassium (K) were 9.16, 43.16, 1.47, 1.07 and 3.84%, respectively. These mean values of nutrients in the cattle manure indicated a high amount of nutrients and it is considered as normal cattle manure for use in crop cultivation (Pholsen *et al*., 2005).

The results on initial and final soil properties of the Korat soil series (Oxic Paleustults) as influenced by production methods and cattle manure rates indicated that soil pH ranges from 4.53-5.44. These values of soil pH may be considered as poor soil conditions since suitable pH values must be within a range from 6-6.5 (1: 2.5, soil: water by volume) in order to achieve a rapid release of soil nutrients (Mengel and Kirkby, 1987; Miller and Donahue, 1990; Suksri, 1998, 1999). Oxic Paleustults, a great soil group is generally known as a poor soil of high acidity with low availability of soil nutrients (Trelo-Ges *et al*., 2002). Both soil organic matter and total nitrogen values were at a moderate level for most tropical soils yet the percentages of the extractable phosphorus (P) were relatively inadequate for growth of the crop plants. An adequate level of the extractable P should not be lesser than 25 ppm whilst the exchangeable potassium (K) should be at least 80 ppm (Mengel and Kirkby, 1987; Suksri, 1999; Kasikranan, 2011). At the end of the experimental period, the soil analysis data revealed that in most cases soil conditions were relatively improved, except that of the extractable P where P values due to treatments were relatively low yet only the high rate of the cattle manure did slightly improve. The results indicated that soil phosphorus available for the third year experimental period was relatively low due to perhaps a large amount of soil P could have been utilized by the second year crop hence a relatively low value of extractable P was attained. However, it was found that the exchangeable K was enormously improved with the application of cattle manure rates, particularly with the highest rate hence cattle manure largely improved soil K. The results confirm the work reported by Pholsen and Higgs (2014).

With the effect due to the treatments on Dry Matter Yields (DMY), the results showed that grass dry matter yields alone increased with an increase in the cattle manure rates. The results indicated that this Korat soil series (Oxic Paleustults) is a relatively poor soil even at the highest cattle manure rate the increase in dry matter yield was not fall hence further experiment with higher rate of cattle manure may be required in order to find out the maximum amount of the DMY. This trend was also found with the effect due to the Production Methods (PM), i.e., a fall on the DMY was not found. However, the effect due to the PM was highest up to the PM3 yet the PM3 was similar to the PM2. Thus the PM2 may be recommended for further use. For grass and legume mixture, the results showed that the highest rate of the cattle manure rates gave the highest DMY although the rate of 8 t ha^{-1} gave a similar DMY to that of the 16 t ha^{-1}. This may be due to the competition between grass and legume plants where the grass plants were able to compete for more nutrients and better growth than the legume plants hence a contribution on the amount of DMY from the legume was relatively small. Nevertheless, the growth of the legume plants together with the Purple Guinea grass could have been partly assisted by cattle manure rates by added more nutrients and improved soil conditions for the growth of the crop plants (Kataoka *et al*., 1994; Pholsen *et al*., 2005, 2014b; Gil *et al*., 2008). The Production Methods (PM) gave the highest DMY with the PM2 only. Thus the PM2 may be recommended for further use. With the results on weeds, the weed dry matter yields were similar in all rates of the added cattle manure where it indicated that all plots with cattle manure rates gave a similar result.

With the grass Crude Protein (CP), an increase in cattle manure rates highly decreased the CP yet the effect due to the production methods was up to the PM2 only indicating that the PM2 was suitable for the grass growing. On the other hand, when the grass plus legumes were grown together, it was found that the CP% due to the production methods was highest with the PM3. This must be attributable to the high amount of dry matter yields of the legume plants assisted in the increased value of the CP%. The decline in the CP% due to an increase in cattle manure rates must be attributable to the high amount of the DMY of the grass diluted the CP% of the legume crops hence the percentages of the CP due to an increase in the cattle manure rates were relatively declined. The results agree with the works reported by Nakamanee *et al*. (2004) and Pholsen *et al.* (2014a). There was a significant interaction between the PM×CM for the grass alone and a highly significant between the PM×CM for the grass plus legume mixture. Thus there is always a need to grow grass plants together with legume crops in order to achieve the utmost benefits. With Neutral Detergent Fiber (NDF) for grass alone, the effect due to an increase in cattle manure rates was significantly found up to 8 t ha^{-1} only further increases gave a similar NDF% yet there was no significant difference due to the production methods found. However, the NDF% of the grass plus legumes was significantly increased with an increase in the cattle manure rates whilst a reverse was found with that of the production methods, i.e., the PM1 ranked the highest and the lowest was with the PM3 hence the production methods decreased the NDF% due to a large amount of the DMY derived from the legume plants. The lower NDF concentrations of the legumes than that of the grasses were reported by Mupangwa *et al*. (1997) and Angthong *et al*. (2004). Therefore, the added amounts of DMY of the legumes decreased the fiber concentrations in the plant tissues. There was no interaction between the PM×CM for the grass alone but highly significant between the PM×CM for the grass plus legume mixture hence again legume is always needed when pastureland must be established. For the grass alone on Acid Detergent Fiber (ADF), the results revealed that the effect due to an increase in the cattle manure rates was found only up to 8 t ha^{-1} and the further increases gave a similar result as that of the 8 t ha^{-1}. The reason for this may be due to a large amount of growth of stems of the legumes where it topped up the total dry matter yields since stems contained a high amount of fibers. It was found that dry matter yields of the legume were higher than that of the grass DMY hence the ADF% of the grass plus legume was relatively declined. There was no interaction between the PM×CM for the grass alone but highly significant for the grass plus legume mixture. Again, legume is always needed for pasturelands where it contributed a relatively high DMY. With Dry Matter Degradability (DMD), it was found that the DMD% in the grass alone did not differ from one another whilst that of the grass plus legume mixture, the DMD% increased with the PM2 only. This may be attributable to the higher amount of lignin contents in the legume plants of the PM3 than that of the PM2 hence the DMD% was lower for the PM3 than that of the PM2. In general, the legume plants may have produced a large amount of lignin when the DMY attained was relatively high hence lower the DMD% of the PM3 than that of the PM2. This could possibly be the case (Pholsen *et al*., 2014b). There was no significant effect between the PM×CM interaction for the grass alone but highly significant for the grass plus legume mixture. Therefore, successful pasture establishment could not do away without the use of the legume crops.

CONCLUSION

To sum up, the results of the third year experiment showed that amount of rainfalls in the rainy season of the 2011 was adequately available for the growth of grass and legume crops. Other contributing factors such as soil pH, nutrients, environmental temperatures and others were at a moderate level as that of the tropical climatic conditions except that of the soil pH values and soil extractable P, which were very low. An increase in the cattle manure rates highly increased dry matter yields of the grass alone and grass plus legume. The high dry matter yields (DMY) of 10,596 and 10,673 kg ha^{-1} were attained with the use of the production method 2 (PM2), where the Verano stylo, Purple Guinea grass plus 24 t ha^{-1} of the cattle manure rates were used and the production method 3 (PM3) where the Wynn Cassia, Purple Guinea grass plus 24 t ha^{-1} of cattle manure were used. The legume crops showed a highly significant role in the amounts of dry matter yields of the pasture production. An increase in the cattle manure rates highly decreased Crude Protein (CP) of the grass alone and the grass plus the legumes. Neutral Detergent Fiber (NDF) for the grass alone increased with an increase in the cattle manure rates up to 8 t ha^{-1} only yet the production methods did not. The NDF% of the grass plus legume highly increased with an increase in the cattle manure rates but a reverse was found with the production methods, i.e., the PM1 had the highest NDF and least with the PM3. The difference was large and highly significant. Acid Detergent Fiber (ADF) for the grass alone highly increased with an increase in the cattle manure rates but the increase for the grass plus legume was only up to 8 t ha^{-1} only. Dry Matter Degradability (DMD) did not increase with an increase in the cattle manure rates yet an increase was found with the PM2 for the grass plus legume.

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