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Soil Nutrients and Liming on Dry Weight Yields and Forage Quality of Signal Grass (*Brachiaria decumbens* Stapf.), Grown on Korat Soil Series (Oxic Paleustults) in Northeast Thailand

Suradej Pholsen

Department of Animal Science, Faculty of Agriculture, Khon Kaen University,
Khon Kaen 40002, Thailand

Abstract: This experiment was carried out at Khon Kaen University Experimental Farm, Khon Kaen University, Thailand during the 2004-2005 aiming to investigate effect of phosphorus (P) and dolomite levels on dry weight yields (DWYs) and forage quality of Signal grass. A 4×3 factorial arranged in a Randomized Complete Block Design (RCBD) was used. Four P levels were: 0, 100, 200 and 400 kg P₂O₅ ha⁻¹ and three dolomite levels were: 0, 625 and 2,500 kg ha⁻¹. The Signal grass plants were grown on Korat soil series, (Oxic Paleustults). A quadrat with a dimension of 50×50 cm was used for grass yield harvests. Crude Protein (CP), Acid Detergent Fibre (ADF), Neutral Detergent Fibre (NDF) and Dry Matter Degradability (DMD) contents were determined. Tissues phosphorus and calcium contents were also analysed. The results showed that an increase in dolomite levels increased soil pH from 4.4 to 5.1 for levels 1 and 3, respectively. An increase in P levels increased available soil P from 4.56 to 28.38 ppm for levels 1 and 4, respectively. For the first year experiment, dolomite levels had no significant effect on DWYs, whilst P levels significantly increased but only up to level 2. The 2-year average DWYs reached 11,368 kg ha⁻¹ for level 4 of P. With the first year rainy season harvests, P levels had its significant effect on ADF and DMD up to level 2 but not with CP and NDF. For the dry season harvests, P and dolomite levels had no significant effects on forage quality. Dolomite levels had no significant effect on P and Ca contents of the Signal grass tissues but an increase in P levels increased P contents. P and Ca contents, in most cases, were higher for the dry season than the rainy season.

Key words: Calcium contents, crude protein, cutting periods, degradability, soil analysis

INTRODUCTION

For most countries in the tropics, pasture and forage crops play its important role in national economy since livestock production depended largely on both amount and quality of forage crops being established for ruminants. Signal grass (*Brachiaria decumbens* Stapf.), one of many important grass species for pasture development could thrive on well in most tropical soils but the utmost production could be achieved only when they are grown under high soil fertility and a good drainage of soil pore spaces (Spain and Andrew, 1977). Most soil series in Northeast Thailand possess high level of soil acidity with a relatively low amount of soil nutrients, e.g., Korat soil series (Oxic Paleustults) analyzed by Sripoon (1992), it revealed that this soil series is a poor sandy loam soil with mean values of pH (1:1, soil:water by volume), organic matter, total nitrogen content (N), available phosphorus (P), exchangeable potassium (K), exchangeable calcium (Ca), exchangeable magnesium (Mg) and sodium (Na) of 4.18, 0.72, 0.057%,

6.75 ppm, 0.038, 0.55, 0.068 and 0.017 meq, respectively. Shelton *et al.* (1979) grown a legume crop viz., *Stylosanthes humilis* on Korat soil series, their results revealed that treatments without an additional amount of P to the soil, an extremely poor production of the crop was attained. Thus many soil series in Northeast Thailand possess inadequate amount of P apart from high level of soil acidity. Thus an inadequate amount of available P prevented high crop yields. Therefore, in every season of crop cultivation, there is an urgent need to add P fertilizer to the soil and soil pH must be improved up to a workable range before sowing of seeds in order to facilitate the rapid release amount of soil nutrients for the crops (Mengel and Kirkby, 1987; Miller and Donahue, 1990; Suksri, 1998, 1999).

Signal grass has been introduced to Northeast Thailand for many decades. It was found that this type of grass species gave much higher production than some other types of grasses and further more it adapted well to drought conditions in the region (Phaikaew *et al.*, 1994). Therefore, it is of important value to carry out more

experiments in order to produce more information on this particular type of grass as to produce the utmost DWYs per hectare. The objectives of this investigation include the search for the responses of the signal grass to different levels of both phosphorus and dolomite on DWYs and forage quality when Korat soil series must be used for pasture establishment in the region.

MATERIALS AND METHODS

The experiment was carried out at the Experimental Farm, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand during the 2004 to 2005 with the use of Korat soil series (Oxic Paleustults) to investigate effects of both phosphorus and dolomite levels on soil property, dry weight yields and forage quality of the Signal grass (*Brachiaria decumbens* Stapf.). A 4×3 factorial arranged in a Randomized Complete Block Design (RCBD) was used. The treatments consisted of 4 application rates of triple super phosphate, i.e., 0, 100, 200 and 400 kg P₂O₅ ha⁻¹ and three rates of dolomite [CaMg (CO₃)₂], i.e., 0, 625 and 2,500 kg ha⁻¹. Thus, there were 12 treatment combinations and each treatment had four replications hence 48 plots were used. The dimension of each plot was a 3×2 m. The land area was ploughed twice followed by harrowing once. The 48 plots were randomly chosen for their respective plots of treatments. All plots received equal amounts of urea chemical fertilizer at a rate of 156.25 kg N ha⁻¹ and also potassium chloride (KCl) at a rate of 125 kg K₂O ha⁻¹. Both N and K chemical fertilizers were applied four times at 42 days interval commencing from a basal dressing at the time after harrowing. Each dolomite rate of respective treatments was divided into two equal portions, i.e., the first half was applied into the respective plots at two weeks before the sowing of Signal grass and the second half was applied at day 1 after the first harvest. All rates of P₂O₅ (triple super phosphate) were applied four times at 42 days interval commencing from day 42 after emergence. Seeds of Signal grass imported from Australia were directly sown in rows into the soil by hand to the depth of approximately 2-3 cm with distances within rows and between rows of 25×25 cm. Right after the sowing of seeds, Carbofuran (3% G), an insecticide, was applied to the soil at a rate of 31.25 kg ha⁻¹ to protect grass seeds from damages made by insect pests. At the same time, Atrazine herbicide was sprayed directly into the plots at a rate of 2.5 kg ha⁻¹ to control the pre-emergence of weed seeds. One week after emergence, thinning of seedlings was carried out leaving only one seedling per hill. Both the same rates and methods of dolomite and chemical fertilizers applications

of the first year experiment were carried out again for the second year experiment.

At 60 days after emergence, the first harvest for grass yield was carried out with the use of a quadrat of 50×50 cm in dimension. The cutting was carried out at 10 cm above ground level. The two subsequent harvests for grass DWYs were carried out at 42 days intervals, i.e., at 102 and 144 days after emergence. This was carried out during the rainy season. Whilst the followed two subsequent harvests carried out in the dry season were taken at 244 and 286 days after emergence. The cutting periods as that of the first year were repeated again for the second year experiment where harvests 1 to 4 were carried out in the rainy season and also harvest 5 was in dry season. The grass yields attained in each cutting were weighed out for fresh weights and then dried in an air dry oven at 60°C for 72 h and finally weighed out again for dry weights. The grass dried materials of each treatment were ground separately to pass through 1 mm mesh screen and then kept in air-tied containers. Ground samples harvested in the rainy season (harvests 1, 2 and 3) were thoroughly mixed together whilst those of the harvests 4 and 5 in the dry season were also added together for forage quality, phosphorus (P) and calcium (Ca) determinations. Crude protein (CP) was determined with the use of Kjeldal method. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined by the method viz. Goering and van Soest (1970) and dry matter degradability (DMD) in the beef cattle rumen at 48 hrs by Nylon bag technique (Orskov *et al.*, 1980). Signal grass tissue analysis for P content was carried out with the use of nitric perchloric digestion and analysed the samples with the use of Atomic Absorption Spectrophotometry equipment and tissue concentration of Ca was determined with the use of Spectrophotometry equipment. The obtained data were statistically analysed using a SAS Computer Programme (SAS, 1998).

RESULTS

Initial and final soil analysis data: For initial soil analysis, the results showed that mean values of pH, organic matter, total soil N, available P and extractable K were 4.4, 0.94 and 0.0414%, 10.15 and 22.50 ppm, respectively. After the 5th harvest of the first year experiment, the final soil analysis data revealed that soil pH due to dolomite levels ranged from 4.4 to 5.1 and for P from 4.7 to 4.9 (Table 1). Mean values of organic matter ranged from 0.95-1.09% for dolomite levels and 0.93-1.10% for P levels. Total soil N ranged from 0.038-0.041% for dolomite levels and 0.037-0.041% for P levels. Available P ranged from

Table 1: Final soil property of Korat soil series (Oxic Paleustults) taken after the 5th harvest of Signal grass of the 1st year experiment as affected by phosphorus and dolomite levels added to the soil, grown at Khon Kaen University Experimental Farm, Northeast Thailand

Dolomite levels (kg ha ⁻¹)	Phosphorus levels (kg P ₂ O ₅ ha ⁻¹)				Average for dolomite
	1 (0)	2 (100)	3 (200)	4 (400)	
Soil pH (1:1 by volume)					
1 (0)	4.500	4.300	4.300	4.600	4.400
2 (625)	4.900	4.500	4.500	4.700	4.700
3 (2500)	5.200	5.000	5.400	4.900	5.100
Average (P)	4.900	4.600	4.700	4.700	
Organic matter (OM %)					
1 (0)	0.979	1.005	0.955	0.913	0.963
2 (625)	0.993	1.030	1.330	1.010	1.091
3 (2500)	0.812	0.945	1.015	1.008	0.945
Average (P)	0.928	0.993	1.100	0.977	
Soil nitrogen (N %)					
1 (0)	0.037	0.037	0.042	0.037	0.038
2 (625)	0.049	0.033	0.037	0.043	0.041
3 (2500)	0.037	0.040	0.040	0.043	0.040
Average (P)	0.041	0.037	0.040	0.041	
Available phosphorus (ppm)					
1 (0)	4.340	11.690	17.690	34.610	17.080
2 (625)	4.340	12.350	26.150	30.600	18.360
3 (2500)	5.010	9.460	18.580	19.920	13.240
Average (P)	4.560	11.170	20.810	28.380	
Extractable potassium (ppm)					
1 (0)	15.960	11.240	15.010	12.660	13.720
2 (625)	12.190	12.190	13.600	15.010	13.250
3 (2500)	17.370	10.770	15.480	10.770	13.600
Average (P)	15.170	11.400	14.700	12.810	

13.24-18.36 ppm for dolomite levels and 4.56-28.38 ppm for P levels. Extractable K ranged from 13.25-13.72 ppm for dolomite levels and 11.40-15.17 ppm for P levels.

Dry weight yields of the first year: The results on Dry Weight Yields (DWYs) of the signal grass harvested in the rainy season of the first year experiment, i.e., the summed up of the initial harvest up to harvest 3, the results revealed that mean values due to dolomite levels ranged from 9,608 to 10,151 kg ha⁻¹ for level 1 and 3, respectively. The difference due to dolomite was not found (Table 2). The effect due to P levels was highest with level 4 (400 kg ha⁻¹) followed by level 3, 2 and 1 with mean values of 11,199, 10,335, 10,127 and 7,658 kg ha⁻¹, respectively. All added P levels gave a similar amount of DWYs but significantly greater than level 1 (without P). With the two subsequent harvests in the dry season, DWYs of all treated grass due to P and dolomite levels were insignificantly found. However, with cumulative DWYs of harvests 1 up to 5, the results indicated that DWYs were similar from levels 2 up to 5 but these levels were significantly higher than level 1.

Dry weight yields of the second year: For the second year DWYs carried out in the rainy season, the cumulative yields of the four sampling periods (harvests 1-4) due to

Table 2: Dry weight yields of harvests 1-3 taken in the rainy season, harvests 4-5 taken in the dry season and dry weight yields of harvests 1-5 of the 1st year experiment as influenced by phosphorus and dolomite levels, grown on Korat soil series (Oxic Paleustults) at Khon Kaen University Experimental Farm, Northeast Thailand

Dolomite levels (kg ha ⁻¹)	Phosphorus levels (kg P ₂ O ₅ ha ⁻¹)				Average for dolomite
	1 (0)	2 (100)	3 (200)	4 (400)	
Dry weight yields of harvests 1-3 of the 1st year in the rainy season (kg ha⁻¹)					
1 (0)	7398	9430	10391	11212	9608
2 (625)	8292	10272	9484	10877	9731
3 (2500)	7285	10680	11131	11509	10151
Average (P)	7658 ^b	10127 ^a	10335 ^a	11199 ^a	
Dry weight yields of harvests 4-5 of the 1st year in the dry season (kg ha⁻¹)					
1 (0)	2701	3013	3382	3456	3138
2 (625)	3611	3243	3199	2953	3251
3 (2500)	3320	3267	3677	3410	3418
Average (P)	3210	3174	3419	3273	
Dry weight yields of harvests 1-5 of the 1st year experiment (kg ha⁻¹)					
1 (0)	10100	12442	13774	14668	12746
2 (625)	11902	13514	12682	13830	12982
3 (2500)	10604	13947	14807	14919	13569
Average (P)	10868 ^b	13301 ^a	13754 ^a	14472 ^a	

Letter(s) indicate least significant differences of Duncan's Multiple Range Test at probability (p) of 0.05.

Table 3: Dry weight yields of harvests 1-4 taken in the rainy season and harvest 5 taken in the dry season of the 2nd year experiment and a 2-year average on dry weight yields of the 1st and 2nd year as influenced by phosphorus and dolomite levels, grown on Korat soil series (Oxic Paleustults) at Khon Kaen University Experimental Farm, Northeast Thailand

Dolomite levels (kg ha ⁻¹)	Phosphorus levels (kg P ₂ O ₅ ha ⁻¹)				Average for dolomite
	1 (0)	2 (100)	3 (200)	4 (400)	
Harvests 1-4 of the 2nd year (kg ha ⁻¹)					
1 (0)	6104	7432	7446	7797	7194 ^b
2 (625)	6691	8032	8557	7592	7718 ^a
3 (2500)	6720	7733	8334	7744	7633 ^a
Average (P)	6505 ^b	7732 ^a	8112 ^a	7711 ^a	
Harvest 5 of the 2nd year (kg ha ⁻¹)					
1 (0)	397	398	478	544	454 ^b
2 (625)	438	625	525	557	536 ^a
3 (2500)	422	557	535	563	519 ^a
Average (P)	419 ^b	527 ^a	513 ^a	554 ^a	
Harvests 1-5 of the 2nd year (kg ha ⁻¹)					
1 (0)	6501	7829	7924	8340	7648 ^b
2 (625)	7129	8657	9082	8148	8254 ^a
3 (2500)	7141	8289	8869	8306	8151 ^a
Average (P)	6923 ^b	8259 ^a	8625 ^a	8265 ^a	
2-year average on dry weight yields (kg ha ⁻¹)					
1 (0)	8300	10136	10849	11504	10197
2 (625)	9515	11086	10882	10989	10618
3 (2500)	8872	11118	11838	11612	10860
Average (P)	8896 ^b	10780 ^a	11189 ^a	11368 ^a	

Letter(s) indicate least significant differences of Duncan's Multiple Range Test at probability (p) of 0.05

dolomite levels showed that DWYs ranged from 7,194 to 7,718 kg ha⁻¹ for levels 1 and 2, respectively (Table 3). The differences were large and statistically significant. DWYs due to P levels ranged from 6,505 to 7,711 kg ha⁻¹ for levels 1 and 4, respectively. Levels 2 up to 4 (added P levels) were similar but significantly higher than level 1.

For the fifth sampling period carried out in the dry season, DWYs due to dolomite levels ranged from 454 to 536 kg ha⁻¹ for levels 1 and 2, respectively. The differences were large and statistically significant. DWYs due to P levels ranged from 419 to 554 kg ha⁻¹ for levels 1 and 4, respectively. DWYs were similar for levels 2 up to 4 (added P levels) but significantly higher than level 1. With the cumulative values of all sampling periods, i.e., from harvests 1 to 5, the results revealed that due to dolomite levels ranged from 7,648 to 8,254 kg ha⁻¹ for levels 1 and 2, respectively. Levels 2 and 3 were similar but significantly higher than level 1. DWYs due to P levels ranged from 6,923 to 8,625 kg ha⁻¹ for levels 1 and 3, respectively. The differences were large and statistically significant but up to level 2 only. With cumulative DWYs of years 1 and 2 together, it was found that a statistical trend on DWYs was similar to those harvested in the rainy seasons of both years, except the effect due to dolomite levels where no significant effect was found. There were no interactions on P×Dolomite on dry weight of the 2 years experiment.

Signal grass forage quality: The results on forage quality carried out during the first year experiment in the rainy season (harvests 1-3) due to dolomite levels on Crude Protein (CP) content revealed that an increase in dolomite levels did not significantly affect CP content with values ranged from 10.97 to 11.26% for level 3 and 1, respectively (Table 4). The values of CP % due to P levels ranged from 11.02 to 11.73% for level 2 and 1, respectively. An increase in P levels did not significantly increase CP content of the Signal grass. With Neutral Detergent Fibre (NDF) content, the results showed that an increase in dolomite and P levels did not significantly affect NDF content with values ranged from 78.08 to 78.15 for dolomite levels and from 77.22 to 78.60% for P levels. For Acid Detergent Fibre (ADF) content, an increase in dolomite levels did not affect ADF contents with values ranged from 40.68 to 41.54%. An increase in P levels significantly increased ADF content but only up to level 2 with values ranged from 39.61 to 42.06 for levels 1 and 2, respectively. An increase in dolomite levels did not significantly increase Dry Matter Degradability (DMD) with values ranged from 66.16 to 67.26% for level 3 and 2, respectively. With P levels, an increase in P levels significantly decreased DMD where all of the added P levels were similar with values ranged from 65.51 to 69.35% for level 4 and 1, respectively.

The results attained with the two harvests (harvests 4-5) in the dry season of the first year experiment showed that CP were similar in all dolomite levels with values ranged from 7.91 to 8.57% for level 1 and 3, respectively

Table 4: Crude Protein (CP), Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) contents and Dry Matter Degradability (DMD) of signal grass of harvests 1-3 of the 1st year experiment taken in the rainy season as influenced by phosphorus and dolomite levels, grown on Korat soil series (Oxic Paleustults) at Khon Kaen University Experimental Farm, Northeast Thailand

Dolomite levels (kg ha ⁻¹)	Phosphorus levels (kg P ₂ O ₅ ha ⁻¹)				Average for dolomite
	1 (0)	2 (100)	3 (200)	4 (400)	
CP (% on DM basis)					
1 (0)	11.51	11.68	10.65	11.19	11.26
2 (625)	11.79	10.52	10.96	11.09	11.09
3 (2500)	11.87	10.87	10.31	10.84	10.97
Average (P)	11.73	11.02	10.64	11.04	
NDF (% on DM basis)					
1 (0)	78.07	78.22	78.36	77.95	78.15
2 (625)	76.97	78.41	78.65	78.29	78.08
3 (2500)	76.62	78.44	78.80	78.46	78.08
Average (P)	77.22	78.36	78.60	78.23	
ADF (% on DM basis)					
1 (0)	39.86	40.95	41.28	40.62	40.68
2 (625)	39.83	42.84	40.49	41.46	41.15
3 (2500)	39.13	42.39	42.34	42.29	41.54
Average (P)	39.61 ^b	42.06 ^a	41.37 ^a	41.16 ^a	
DMD (% on DM basis)					
1 (0)	69.42	65.12	67.35	65.09	66.74
2 (625)	69.39	66.05	67.30	66.29	67.26
3 (2500)	69.24	65.65	64.60	65.15	66.16
Average (P)	69.35 ^a	65.61 ^b	66.42 ^b	65.51 ^b	

Letter(s) indicate least significant differences of Duncan's Multiple Range Test (DMRT) at probability (p) of 0.05

Table 5: Crude PROTEIN (CP), Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) contents and Dry Matter Degradability (DMD) of signal grass of harvests 4-5 taken in the dry season of the 1st year as influenced by phosphorus and dolomite levels, grown on Korat soil series (Oxic Paleustults) at Khon Kaen University Experimental Farm, Northeast Thailand

Dolomite levels (kg ha ⁻¹)	Phosphorus levels (kg P ₂ O ₅ ha ⁻¹)				Average for dolomite
	1 (0)	2 (100)	3 (200)	4 (400)	
CP (% on DM basis)					
1 (0)	8.03	7.96	7.89	7.79	7.91
2 (625)	8.62	7.80	8.06	7.80	8.07
3 (2500)	8.56	8.91	7.99	8.84	8.57
Average (P)	8.40	8.22	7.98	8.14	
NDF (% on DM basis)					
1 (0)	73.65	72.21	72.75	73.60	73.05
2 (625)	71.49	72.25	73.59	73.84	72.79
3 (2500)	72.62	70.49	73.95	73.68	72.68
Average (P)	72.59	71.65	73.43	73.71	
ADF (% on DM basis)					
1 (0)	35.78	36.00	36.27	36.17	36.05
2 (625)	35.18	36.11	36.05	35.50	35.71
3 (2500)	36.89	35.17	36.61	35.16	35.96
Average (P)	35.95	35.76	36.31	35.61	
DMD (% on DM basis)					
1 (0)	69.34	68.96	68.75	66.45	68.37
2 (625)	69.17	67.42	68.13	68.01	68.18
3 (2500)	68.25	70.09	67.20	70.62	69.04
Average (P)	68.92	68.82	68.02	68.36	

Letter(s) indicate least significant differences of Duncan's Multiple Range Test (DMRT) at probability (p) of 0.05

(Table 5). With P levels, CP values ranged from 7.98 to 8.40% for level 3 and 1, respectively. An increase in dolomite and P levels did not affect NDF content with values ranged from 72.68 to 73.05 % for dolomite and from

71.65 to 73.71% for P levels. ADF values due to dolomite levels ranged from 35.71 to 36.05% for level 2 and 1, respectively. An increase in dolomite levels did not increase ADF content. ADF values due to P levels ranged from 35.61 to 36.31% for level 4 and 3, respectively. The DMD values due to dolomite levels were similar and the values ranged from 68.18 to 69.04 for level 2 and 3, respectively. The DMD values as affected by P levels gave a similar trend to that of the dolomite with values ranged from 68.02 to 68.92 for level 3 and 1, respectively. There were no interactions on P×dolomite on forage quality both the rainy and dry seasons.

Tissue analysis on phosphorus and calcium contents:

With harvests 1-3 of the first year, the results due to dolomite levels showed that mean values of phosphorus (P) content in the signal grass tissues ranged from 0.402 to 0.428 for levels 3 and 1, respectively (Table 6). An increase in dolomite levels decreased P content. P tissue contents increased with an increase in P levels with values ranged from 0.315 to 0.523% for level 1 and 4, respectively. With calcium (Ca) content due to dolomite levels, it was found that an increase in dolomite levels increased Ca content in all added levels. An increase in P levels increased Ca content up to level 2 and then all of the added levels were similar.

For the dry season harvests (harvests 4-5) due to dolomite levels, an increase in dolomite decreased P contents with values ranged from 0.447 to 0.461% for

level 2 and 1, respectively. P tissue contents increased with an increase in P levels with values ranged from 0.275 to 0.635% for level 1 and 4, respectively. For Ca tissue content, an increase in dolomite levels increased Ca content in all levels but level 3 was slightly smaller than level 2 with values ranged from 0.287 to 0.310% for level 1 and 2, respectively. With the effect due to an increase in P level, the results showed that an increase in P levels increased Ca tissue contents in all P levels yet level 3 was slightly lower than both level 2 and 4 with mean values ranged from 0.261 to 0.330% for level 1 and 4, respectively.

DISCUSSION

For crop cultivation in many tropical countries, growers have been facing many obstacles in producing high crop yields for a number of decades, e.g., soil types, drought conditions, poor soil fertility, insect pests, high soil acidity, heavy rainfall where it causes a high leaching rate, soil erosion and many others. However, in spite of the inappropriate conditions of these contributing factors, growers realized that they attain free radiant energy from the sun, carbon dioxide from the atmosphere and rainfalls. Soil condition is one of many important contributing factors, i.e., when the soil is not at an ideal condition, particularly soil property then method in improving soil condition must be applied. For this Korat soil series (Oxic Paleustults), it has been reported that soil property values on pH and phosphorus contents were relatively low (Shelton *et al.*, 1979; Sripoon, 1992) hence an initial experiment should emphasize on these two contributing factors. This is to establish some data on the improvement of soil conditions when some certain amounts of both dolomite and phosphorus are used.

From initial soil analysis data, it revealed that mean values of soil pH and available phosphorus (P) were 4.4 (1:1 soil:water by volume) and 10.5 ppm, respectively. For this Signal grass experiment both values of soil pH and available P were extremely low for high crop yields. The poor mean values of soil pH and available P must be attributable to the previous history of crop cultivation and many other reasons such as the depletion of soil nutrients and high leaching rate. At the fifth harvest, mean values of soil pH have steadily increased up to a value of 5.1 for the highest level of dolomite application (2,500 kg ha⁻¹). The results indicated that an increase in dolomite levels increased mean values of soil pH. However, this highest mean value of soil pH was not adequate enough for crop growth. Suksri (1999) stated that for a high crop yield, this Oxic Paleustults great soil group should possess a range of soil pH values from 6 to 6.5 (1:2.5 soil:water by volume). This range of soil pH values has been recommended for high crop yields where some certain amount of soil

Table 6: Tissue analysis on phosphorus and calcium contents of Signal grass during the first year experiment (harvests 1-3 carried out in the rainy season and harvests 4-5 in the dry season) as affected by phosphorus and dolomite levels, grown on Korat soil series (Oxic Paleustults) in Northeast Thailand

Dolomite levels (kg ha ⁻¹)	Phosphorus levels (kg P ₂ O ₅ ha ⁻¹)				Average for dolomite
	1 (0)	2 (100)	3 (200)	4 (400)	
Rainy season (harvests 1-3):					
Phosphorus (%)					
1 (0)	0.327	0.374	0.457	0.553	0.428
2 (625)	0.310	0.370	0.422	0.519	0.405
3 (2500)	0.308	0.377	0.426	0.498	0.402
Average P	0.315	0.374	0.435	0.523	
Calcium (%)					
1 (0)	0.186	0.219	0.238	0.229	0.218
2 (625)	0.206	0.265	0.265	0.247	0.246
3 (2500)	0.198	0.280	0.257	0.274	0.252
Average P	0.197	0.255	0.253	0.250	
Dry season (harvests 4-5):					
Phosphorus (%)					
1 (0)	0.290	0.398	0.508	0.647	0.461
2 (625)	0.253	0.404	0.464	0.666	0.447
3 (2500)	0.281	0.406	0.518	0.591	0.449
Average P	0.275	0.403	0.497	0.635	
Calcium (%)					
1 (0)	0.240	0.308	0.288	0.311	0.287
2 (625)	0.269	0.331	0.306	0.334	0.310
3 (2500)	0.273	0.333	0.298	0.325	0.307
Average P	0.261	0.324	0.297	0.330	

nutrients could be adequately released. Thus, the highest level of dolomite being added to the Korat soil series was not able to raise a soil pH value to a workable level for the Signal grass. Thus some higher amounts of dolomite must be added to the soil. Within the suitable range of soil pH, high quality of forage Dry Weight Yields (DWYs) could possibly be achieved. That is at least some large amounts of Ca contents in the forage tissues must be attained. This could be one way to improve milk quality of the dairy cattle, apart from beef production. Another point to improve soil condition of this soil type is to increase level of soil potassium (K), the results on soil analysis revealed that an amount of extractable K was not exceeded 20 ppm. This amount was extremely inadequate for high crop yield where any soil type in the tropics should contain at least 80 ppm of extractable K (Suksri, 1998, 1999; Pholsen *et al.*, 2001; Rapatsa and Terepongatanakorn, 2010).

For DWYs of the first year harvests, the results showed that an increase in dolomite levels had no effect on dry weight yields. This may be attributable to the low mean values of soil pH where the highest dolomite level gave a mean value of 5.1 only, thus it may be possible that only a small amount of each needed element was released in soil due to perhaps a high leaching rate occurred in the past crop cultivation with this sandy soil type in the tropics (Miller and Donahue, 1990). However, when it comes to the effect due to phosphorus (P), an increase in P levels significantly increased DWYs of the Signal grass but the increase was only up to level 2 (100 kg P_2O_5 ha⁻¹). This must be due to other contributed factors, e.g., low total soil N as reported by Pholsen *et al.* (2005) and Thinnakorn *et al.* (1998). They also reported that with a soil pH mean value of 6.64, an increase in N fertilizer application rate added to the soil significantly increased Signal grass dry weight yields. Another reason must be due to the low amount of extractable K in soil. It was found that extractable K was relatively low where the mean value was lesser than 20 ppm. K has its significant role in photosynthetic activities such as in the process of loading and unloading of assimilates from source (leaves) to sink (stems). The translocation of assimilates from source to sink is assisted by K where it helps in the process of translocation of assimilates by its influences on electron (e⁻) transport in the transport chain (Overnell, 1975; Mengel and Kirkby, 1987; Suksri, 1998, 1999). Although, the amount of available P of level 3 was considerably adequate (20.81 ppm), but no further increases in dry matter yield were attained. This available P in soil derived from level 3 could possibly be considered sufficient for growth of the signal grass. A range of available P between 20-30 ppm has been confirmed for high crop yields by a number of workers, e.g., Suksri (1998, 1999) and Pholsen *et al.* (2001). A similar trend on

DWYs due to effect of P was attained with the second year experiment but the yields were slightly smaller. The effect due to the added dolomite levels indicated that an increase in dolomite levels significantly increased DWYs but only up to level 2 (625 kg ha⁻¹). The results indicated that dolomite levels could improve mean value of soil pH where other macronutrients could be rapidly released such as with the case of K but it turns out that K source was limited due to the low supply in soil hence dry matter yield was limited. The highest level of dolomite added to the soil gave a mean value of soil pH only up to 5.1 so with this soil type a higher level of dolomite perhaps more than 3,000 kg ha⁻¹ should be required in order to raise a soil pH value to 6 or 6.5. It was found that an average dry matter yield of the two-year experiment of the signal grass of this current work (11,368 kg ha⁻¹) were lower than those reported by Phaikaew *et al.* (1994), Waipanya *et al.* (1999) and Pholsen *et al.* (2005) where they attained DWYs of 16,236, 12,081 and 13,824 kg ha⁻¹, respectively. This could have been due to the lower mean values of soil pH, nitrogen and extractable potassium of this current work, which were, in most cases, lower than the works of these cited publications.

With forage quality of the first three harvest carried out in the rainy season, Crude Protein (CP) contents, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Dry Matter Degradability (DMD) were not significantly affected by dolomite levels. The results suggested that dolomite had no effect on forage quality of the signal grass. This could possibly be due to the low levels of dolomite added to the soil resulted in the low values of soil pH hence small released amounts of soil nutrients were relatively available. The CP percentages attained with this work were much higher than those reported by Phaikaew *et al.* (1994), Sukkasem *et al.* (2003) and Vorajeravamich *et al.* (2006). The differences could have been due to perhaps the harvesting age, i.e. the longer the duration on harvesting age for DWYs the greater the fibrous contents hence CP content was decreased.

When it comes to the effect due to phosphorus (P) levels, it was found that ADF was significantly affected by P levels, whilst CP and NDF were not. The significant effect due to P levels on ADF was only up to level 2. On the contrary, DMD significantly decreased with an increase in P levels. The results indicated that the higher the P level the lower the value of digestibility. This must be due to the increased amount of fibrous contents in the forage tissues due to higher P levels. Since, P has its significant role in biochemical processes on cell division and it could also stimulate cell aging (Miller and Donahue, 1990). Kavanova *et al.* (2006) reported that P deficiency led to a reduction of leaf elongation rate up to 39% due to

the decreases in cell production rate (-19%) and final cell length or elongation (-20%). Therefore, there was some significant difference found on ADF contents, i.e., all P added treatments (level 2-4) gave significantly higher ADF contents than P of level 1. This led to the higher DMD value of no added P (level 1) than all other added P treatments (level 2-4). The results agreed with the work reported by Reid and Jung (1965) where they reported that an additional P to the soil increased ADF contents. With the two harvests in the dry season, the results revealed that dolomite and P levels added to the soil had no significant effect on forage quality. This must be due to the low level of soil moisture contents in the dry season where vegetative growth of the Signal grass was relatively small. That is why CP and DMD values were much lower than those attained in the rainy season, thus a poor quality of forage grass was attained.

For forage tissue analysis carried out in the rainy season (harvest 1-3), an increase in dolomite levels had no significant effect on P content, whilst an increase in P levels increased P content where the increase was up to the highest level of P (level 4) and it was found that DWYs of the Signal grass had also increased with an increase in P levels added to the soil. This must be attributable to the amounts of available P in soil, i.e., the more the amount of available P the greater the percentages taken up by the grass plants. This result confirmed the work reported by Evers (2002), i.e., P uptake in the plant tissues was related to forage production. Phosphorus and calcium percentages in the Signal grass tissues were much higher than those reported by Thinnakorn *et al.* (1998) and Sukkasem *et al.* (2003) but similar to those reported by Aregheore *et al.* (2006, 2007). Minson (1990) reported that a beef cattle with live weight of 200-600 kg requires amounts of phosphorus in forage from 0.8-2.5 g kg⁻¹ dry matter (DM) day⁻¹ and calcium from 1.2-4.4 g kg⁻¹ DM day⁻¹, with this current work it was found that P and Ca contents in the forage reached the requirements where they derived from P application at a rate of 100 kg P₂O₅ ha⁻¹ and Ca at a rate of 625 kg ha⁻¹. This treatment gave Ca of 2.65 and 3.31 g kg⁻¹ and P of 3.70 and 4.04 g kg⁻¹ for both the rainy and dry seasons, respectively. Nevertheless, for Friesian dairy cattle, Minson (1990) also found that a cow with live weight of 600 kg produced milk of 0, 10, 20 and 30 kg day⁻¹ requires P of 1.6, 2.3, 3.1 and 3.8 g kg⁻¹ DM day⁻¹ and Ca of 1.7, 2.6, 3.4 and 4.2 g kg⁻¹ DM day⁻¹, respectively. For this current work it was found that Ca contents were slightly lower than the requirements for dairy. It was found that in the dry season, in most cases, P and Ca contents were higher than in the rainy season. This could possibly be attributable to the differences in DWYs where DWYs attained in the rainy season were much higher than in the

dry season. The larger amount of dry weight yields attained in the rainy season than the dry season could possibly have diluted the concentration of nutrients in the grass tissues. Further experiment should be carried out, particularly with the use of different levels of potassium chemical fertilizer in order to attain more information on how the signal grass responds to different rates of the applied potassium.

CONCLUSIONS

The Korat soil series (Oxic Paleustults) possessed a high level of soil acidity with low mean values of available phosphorus (P) and extractable potassium (K), an increase in dolomite level increased soil pH (up to 5.1) but the increase was not up to the workable level (6-6.5: soil: water by volume). Similarly, an increase in phosphorus level increased available soil P in all added levels (up to level 4). Level 2, 3 of P was considerably adequate for growth of the signal grass. An increase in P level significantly increased DWYs of both first and second year experiment but the increase was only up to level 2. All added dolomite levels had no effect on CP, NDF, ADF and DMD in both rainy and dry seasons of the first year harvests. For the rainy season harvests of the first year, all added P levels had no significant effect on CP and NDF contents but significantly affected ADF and DMD, which was found only with level 2. There was no significant effect due to P and dolomite levels found in all forage quality. P contents in the signal grass tissues harvested in both the rainy and dry seasons slightly decreased with an increase in dolomite levels while Ca contents increased. P contents increased with an increase in P levels in both seasons. P percentages were, in most cases, higher for the dry season than rainy season.

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