Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 7 (5): 687-694, 2007
ISSN 1812-5654

The Use of Slurry for Managing Forage Mixtures in Temperate Brown Forest Soils

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Abstract: To investigate the effects of slurry on grass-legume mixture with a range of harvesting time in the temperate region, experiments were carried out during the 2002 and 2003 growing season at Tanohata, northeast Honshu Island of Japan. Three locations were chosen namely Haruo, Isao and Seiichi. In 2002, irrespective of the locations or forage ratios, the highest level of dry matter was obtained in April and the lowest in October. One the other hand, in 2003, the reverse of the 2002 result was observed. Dry matter production was highest in Seiichi due to the high proportion of Italian ryegrass species. Crude protein was highest in the Haruo field. Crude fiber and acid detergent fiber were highest in the Seiichi field. Irrespective of the time of harvest or year of harvest, the Haruo field showed the highest levels of K, Ca, Mg, Fe and Se than the other fields. On the other hand, the Isao field showed higher values for Mn, I and Ni than the other fields. The highest level of Cl was found in the Seiichi field. Generally, the Ca/P and Cu/Mo ratios were noted to be adequate for livestock production for all the locations. Grass tetany risk declined with increasing number of harvest as well as white clover ratios replaced with orchardgrass and/or Italian ryegrass. In accordance with dietary requirements for cattle, concentrations of P, K, Ca, Cl, Fe, Mn, Mo, Co, I, Ni and Se in the grass-legume mixture were remarkably high and N, S and Cu showed adequate levels.

Key words: Brown forest soil, forage mixture, slurry, digestibility components, nutrient content

INTRODUCTION

Due to rapid increase of human as well as livestock populations there is a pressing need to expand the cultivable land throughout the world. A common shortage of livestock feed in the temperate region and elsewhere in rain-fed areas, where animals are mostly fed below their optimum requirement necessary to achieve desired productivity is well documented. The number of livestock in Japan has been increasing after World War II. The large number of livestock produces a lot of excreta, which is a threat to environmental sanitation. In Japan, the production of forage grasses is also increasing due to the food diversity of the Japanese people just like the attempt to optimum levels of feed. In the northern part of Japan, orchardgrass, Italian ryegrass, Kentucky bluegrass and white clover are frequently grown as sole forages. In agricultural lands, slurry is commonly used to improve soil fertility and crop yield. Excessive slurry applications can, however, result in concentration of toxic levels of certain elements in plant tissue and soil. Among the problems that can arise from heavy application of slurry is the potential occurrence of grass tetany, a metabolic disorder in grazing animals, which can result in animal death. Perennial ryegrasses such as orchardgrass (*Dactylis glomerata* L.) and tall fescue (*Lolium arundinaceum* [Schreb.] SJ Darbyshire) were among species implicated in grass tetany (Sleper, 1979). Many studies on animal manure and its effect on forages indicate various responses regarding grass tetany potential of different forages. Heavy application of fresh farmyard manure to maize (*Zea mays* L.) and Italian ryegrass (*Lolium multiflorum* Lam.) grown on Andisols resulted in K/(Ca+Mg) ratio above 2.2 (Ito and Miyazawa, 1984), which was considered as grass tetany risk (Kemp and t'Hart, 1957). Changes in chemical composition of plant parts and the sward structure of grasses occur with advancing maturity of plant. These changes cause the nutritive value of cool-season grasses to decrease with advancing maturity. This can be attributed to decrease in forage digestibility and crude protein concentration (Kilcher and Troelsen, 1973; Buxton and Marten, 1989) and increase in fibre and lignin concentration (Sanderson and Wedin, 1989; Belanger and McQueen, 1996; Hockensmith *et al.*, 1997).

White clover, as a legume is well adapted to the humid parts of the temperate zone throughout the world on wide range of soil types. In general, legumes such as white clover showed highest values for Ca and Mg concentrations and lower for K/(Ca+Mg) ratio

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(Rahman *et al*., 2003). Legume grown mixed with grasses also provides advantages for hay production over grasses grown in monoculture (Berdahl, 2001). Many studies have documented that legumes complement grasses by increasing total yield and protein concentration of herbage. Incorporating forage legumes with grasses may not only increase the forage yield but also supply nutritious feed to animals. When forages are grown mixed with grasses, they may meet some of their N requirement from that provided by companion legumes. Legumes may also generally benefit from the presence of grasses (Vallis *et al*., 1976; Craig *et al*., 1981; Carlson *et al*., 1985). But whether such practices are sustainable in the temperate region of Japan is not very clear. Furthermore, the effects of slurry on grass-legume mixture ratios in the temperate region all over the world are not well documented. Thus, our objective was to evaluate the response of forage mixtures to the application of slurry in temperate brown forest soils. This study focused on dry matter production, digestibility traits and nutrient concentration of forage mixtures.

MATERIALS AND METHODS

Experimental site and soil characteristics: The experiment was conducted during 2002 and 2003 at Tanohata Mura located at the northeastern Honshu Island of Japan. Three locations with different soil types, fertility and physiography namely, Haruo (sandy loam), Isao (sandy clay loam) and Seiichi (sandy loam) and two sites from each of the locations were selected for this study. These sites represent typical grazing land characterized by brown forest soils. The experimental sites which were established in 1980, were located at approximately latitude of 39°55′ N and longitude 141°53′ E with the altitude of 156-160 m above sea level. The climatic conditions of the study areas are shown in Fig. 1. Orchardgrass (*Dactylis glomerata* L.), Italian ryegrass (*Lolium multiflorum* Lam.), Kentucky bluegrass (*Poa pratensis* L.) and white clover (*Trifolium repens* L.) mixture ratios were considered (Table 1) and three harvest times were imposed. The soils of the experimental field were collected in October 2001 and analyzed for physico-chemical properties. The soils of the fields are brown forest soils having moderately acidic pH and medium to high organic matter (Table 2) with different nutrient status (Table 3).

Experimental design and treatments: The grass species were allowed to grow with the application of slurry at a rate of 32850, 17500 and 79790 kg ha^{-1} to Haruo, Isao and Seiichi fields, respectively, accompanied by chemical

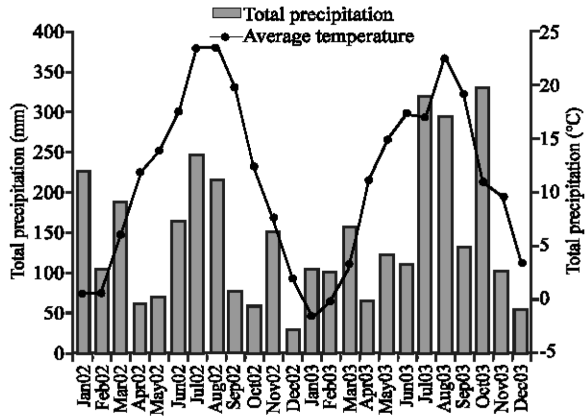

Fig. 1: Monthly total precipitation and temperature of study area

fertilizers of 49 kg N, 73.5 kg P_2O_5 and 17.5 kg K_2O ha^{-1} to Haruo field, 80.4 kg N, 168 kg P_2O_5 and 84 kg K_2O ha^{-1} to Isao field and 252 kg N, 378 kg P_2O_5 and 90 kg K_2O ha^{-1} to Seiichi field in 2002. In 2003, slurry application to the grassland was increased to the maximum and as a result chemical fertilizers were reduced to the minimum (Seiichi field). In addition, the application rates were also chosen in accordance with the N, P and K budgets for the 2003 growing season. Grass species were grown with the applications of slurry at a rate of 64470, 28000 and 140000 kg ha^{-1} at Haruo, Isao and Seiichi fields, respectively, accompanied by chemical fertilizers of 49 kg N, 73.5 kg P_2O_5 and 17.5 kg K_2O ha^{-1} at Haruo, 80.4 kg N, 168 kg P_2O_5 and 84 kg K_2O ha^{-1} at Isao and 147 kg N, 221 kg P_2O_5 and 52.5 kg K_2O ha^{-1} at Seiichi in 2003. At the Haruo site, chemical fertilizer was applied once (April) in a growing season but in the case of Isao, 60% was applied in April and 40% in July. At the Seiichi site, 55% chemical fertilizer was applied in April and 45% in June. The chemical fertilizer application was below the optimum dose to grassland for both the years (Saiga *et al*., 2002). All the fields received slurry just after each harvests at the rate of one quarter of the total slurry applied. The slurry applied to the fields was different in nutrient status (Table 3) with the pH of 7.2, 9.1 and 8.1 in 2002 for Haruo, Isao and Seiichi, respectively. In 2003, pH levels were 7.5, 9.4 and 7.6 in 2003 Haruo, Isao and Seiichi, respectively.

Harvesting and measurements: Forages were harvested three times on 6 April (First harvest), 30 July (Second harvest) and 9 October (Third harvest) to 6 cm cutting height as composite samples. The samples were collected randomly with eight replications for each harvest. Thereafter, composite samples were separated into different species and then their fresh weight was

Table 1: Composition of species across two years

		Composition of species (%)											
		Orchardgrass		Italian ryegrass		White clover		Kentucky bluegrass		Fallow		Weed	
Field	Harvest	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Haruo	1	28	51	0	0	32	28	20	21	15	0	5	0
	2	37	28	0	0	33	2	10	70	15	0	5	0
	3	47	55	0	0	20	3	33	40	0	0	0	2
	Mean	37	45	0	0	28	11	21	44	10	0	3	1
Isao	1	100	100	0	0	0	0	0	0	0	0	0	0
	2	45	100	15	0	15	0	5	0	10	0	10	0
	3	68	100	0	0	12	0	0	0	10	0	10	0
	Mean	71	0	5	0	9	0	2	0	7	0	7	0
Seiichi	1	45	92	32	8	0	0	13	0	5	0	5	0
	2	5	24	65	69	0	0	5	0	20	0	5	7
	3	78	56	18	43	4	0	0	0	0	0	0	1
	Mean	43	57	38	40	1	0	6	0	8	0	3	3

Table 2: Physical properties of soils collected from three fields

Parameter	Unit	Haruo	Isao	Seiichi
Elevation	m	160	159	156
Soil depth	cm	7	8	12
Color	-	10YR6/2	10YR6/3	10YR3/3
Structure	-	Structureless	Granular	Crumb
Stickiness	-	Non-sticky	Very sticky	Slightly sticky
Sand	%	66.8	61.1	58.8
Silt	%	20.0	15.7	38.9
Clay	%	13.2	23.2	2.2
Textural class	-	Sandy loam	Sandy clay loam	Sandy loam
Hardness	$kg\ cm^{-2}$	7.3	10.9	7.9
Bulk density	$Mg\ m^{-3}$	1.69	1.58	1.45
Porosity	%	51.4	51.0	65.5
Solid phase	%	48.6	49.0	34.5
Liquid phase	%	49.8	50.7	62.9
Gas phase	%	1.62	0.32	2.53
MWHC[1]	%	48.1	57.7	89.8
FC[2]	%	45.4	54.6	86.9
HM[3]	%	2.70	4.60	9.82

[1]MWHC = Maximum water holding capacity; [2]FC = Field capacity, [3]HM = Hygroscopic moisture

Table 3: Chemical properties of soil and slurry for various fields

	Haruo			Isao			Seiichi		
	Soil	Slurry[1]		Soil	Slurry		Soil	Slurry	
Element	2001	2002	2003	2001	2002	2003	2001	2002	2003
pH	6.09	7.20	7.50	5.26	9.10	9.40	6.32	8.10	7.60
%OM	2.89	-	-	6.16	-	-	14.1	-	-
				$g\ kg^{-1}$					
N[2)]	1.20	42.2	49.9	1.50	45.5	60.5	5.50	59.2	58.1
Na	8.27	7.25	8.10	1.56	44.6	49.9	3.27	6.2	8.1
Mg	20.9	10.8	10.0	20.0	6.6	5.1	18.1	8.5	9.4
Si	123	8.4	10.4	119	3.5	2.8	110	16.7	14.4
P	1.48	14.8	12.7	0.68	0.3	0.8	1.84	9.90	11.6
S	0.48	6.4	8.6	0.40	35.1	28.6	0.51	5.6	6.4
Cl	nd[3]	14.6	18.3	nd	39.6	80.8	nd	20.9	24.3
K	4.68	44.8	58.8	7.03	24.4	22.6	3.54	59.4	72.6
Ca	8.04	23.8	23.0	1.54	2.2	2.0	5.67	21.3	27.3
Fe	9.44	1.04	1.19	2.3	0.56	0.17	2.3	2.05	0.81
				$\mu g\ g^{-1}$					
Mn	317	269	230	333	296	237	289	191	247
Co	nd	2.5	4.00	nd	33.8	27.3	nd	1.5	15
Ni	7.5	5.0	11.3	9.25	29.3	8.0	7.5	8.0	5.5
Cu	2.0	19.8	10.3	nd	9.8	4.5	nd	27.5	7.25
Zn	23.3	122	115.0	25.0	7.0	8.8	43.3	137	92.5
Se	5.5	8.0	1.3	4.25	5.3	12.8	nd	3.3	11.8
Mo	4.5	0.8	4.5	5	13.0	9.0	nd	12.0	10.8
I	256	10.0	119.0	866	274	538	214	16.0	327

[1]Slurry was freezed dry and then measured; [2]Kjeldahl method; [3]Not detected

measured. The compositions of grass species were not uniform for three successive harvests done over the two years. Problematic soils and adverse climatic conditions restricted the regrowth of few species. Dry weight of plant samples were recorded after being dried at 80°C for 24 h in a forced-air oven. Dried samples were ground to pass through a 0.5 mm mesh with a cyclone mill and 0.5 to 1.0 g sample was pressed (with a coherent disc of 2.5 cm) by applying 15.0 tons pressure to make a pellet with a uniform surface. Concentrations of sodium (Na), magnesium (Mg), silicon (Si), phosphorus (P), sulfur (S), chlorine (Cl), potassium (K), calcium (Ca), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), selenium (Se), molybdenum (Mo) and iodine (I) at both surfaces of the pellet were measured with a live time of 100s by energy reflectance x-ray fluorescence analyzer (ERF; JEOL Co., JSX-3220, Element Analyzer) as described by Hutton and Norrish (1977) and Norrish and Hutton (1977). Each plant sample was replicated three times. The K/(Ca+Mg) was computed on a mole equivalent basis. The crude protein (CP), crude fat (CFAT), crude fiber (CFIB), acid detergent fiber (ADF), organic cell wall (OCW), organic cell content (OCC) and low digestible cell content (Ob) were determined by near infrared spectroscopy (NIRS 6500; NIRSystem Co.) using samples screened through 0.5 mm with a cyclone mill. Digestible Protein Percent (DPP) was estimated according to the method of Conrad and Martz (1985). The total nitrogen (N) content was measured by the Kjeldahl method and calculated (Pearson and Ison, 1987) according to the percent composition of the species in each field.

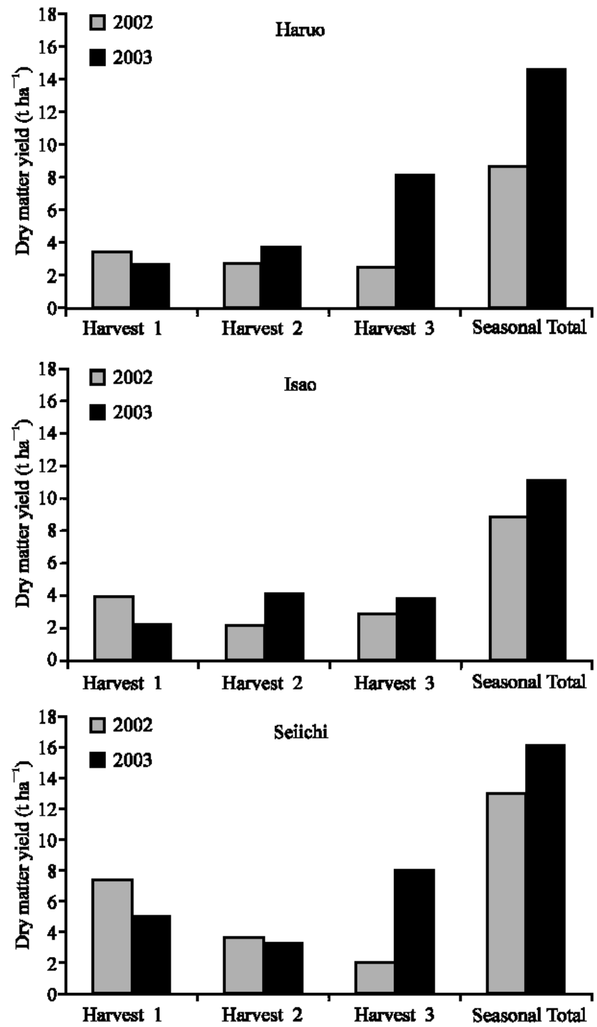

Fig. 2: Dry matter yield (t ha^{-1}) of composite forage mixture of each field

RESULTS AND DISCUSSION

In the present study, the effects of slurry on orchardgrass-Italian ryegrass-Kentucky bluegrass-white clover mixture ratios grown on brown forest soils in the temperate region of Japan and forage quality were investigated. Distinct differences were found in dry matter production between crop mixture ratios and between different harvest times (Fig. 2). The compositions of grass species were not uniform for successive three harvests and problematic soils and adverse climatic conditions inhibited the regrowth of few species. For Haruo, Isao and Seiichi total dry matter yielded 8.63, 8.94 and 13.0 t ha^{-1} in 2002 and 14.5, 11.1 and 16.0 t ha^{-1} in 2003, respectively. Dry matter production in Seiichi was highest and this was due to the proportion of different grass species. Furthermore, pH, organic matter content and water holding capacity of the Seiichi field were comparatively more suitable than those of the other fields. The relatively better Seiichi field was due to the better quality slurry applied in terms of total nitrogen content (Table 3) as well. The highest dry matter yield was observed in April (First harvest) and the lowest in October (Third harvest) for all the sites in the 2002 growing season. On the other hand, in the 2003 growing season, 56, 43 and 49% total dry matter yield occurred in the October harvest (Third harvest) as slurry application was increased to 96, 60 and 76% in Haruo, Isao and Seiichi fields, respectively. Higher amount of yield during the late season could be more valuable in economic terms since hay-crop or stored forage could fetch more money in the lean season. In 2003, the levels of accumulated dry matter production were 68, 24 and 23% higher than in 2002 at the Haruo, Isao and Seiichi sites, respectively. Dry matter production was increased as the growing season progressed and this may be due to increased application of slurry and which in turn might have increased the proportion of orchardgrass. In 2002 and 2003, DM yields of grass-legumes averaged 10.2 and 13.9 t ha^{-1}, respectively from three harvests at all locations while grass monocultures viz. Italian ryegrass and orchardgrass grown in a comparable environment in the Honshu Island of Japan, averaged 10.9 and 9.71 t ha^{-1}, respectively, from four harvests (Sabreen, 2004).

Table 4 shows digestibility components in different harvest of various fields. The Haruo site showed the highest crude protein (CP) concentration of swards. In the present study, the Haruo field has more legume than Isao and Seiichi sites (Table 1). Crude protein concentrations generally decreased as the growing season progressed. It is evident from the result that CP was highest in the mixtures with higher white clover ratios. On the other hand, CP was lowest in the mixtures with higher Italian ryegrass ratios. Legumes generally contain more protein than grasses, especially at the more mature growth stages. Increased CP resulting from fertilizer N addition to grasses (George *et al*., 1973) or from N_2 fixation by accompanying legume has been extensively documented (Farnham and George, 1994; West and Wedin, 1985). Well culled dairy cows require 16-18% of their dietary DM as protein. Thus, forages having 18% or more protein may be used to meet almost all the needs of high producing cows for milk production (Conrad and Martz, 1985). Highest digestible protein percentage (DPP) was observed in the Haruo field followed by Isao and the lowest was in Seiichi. Acid detergent fiber (ADF) concentrations generally decreased with increasing number of harvest. Although differences in ADF concentration existed, they were not large. The highest ADF was observed in the Seiichi field and the lowest was in Haruo. According to Van Soest *et al*. (1991), ADF is an indicator of forage digestibility in ruminants. Reduction in ADF concentration would be desirable for the improvement of forage grasses.

Sulfur and minerals like Ca and Mg in herbage may influence forage quality by improving fiber digestibility (Spears, 1994). Table 5 and 6 show mineral element contents in different harvests at the three sites. Magnesium and S content increased gradually with increasing number of harvest in all the fields and highest levels were recorded in the third harvest for all the fields. With few exceptions, the values for P, K, Si and Cu increased from the first harvest to the second and then decreased. Thus, the highest levels of P, K, Si and Cu were in the second harvest for all the fields. Calcium and Fe contents increased gradually with increasing number of harvest for Isao and Seiichi fields. Calcium and Fe contents of the Haruo site did not follow the trend observed in Isao and Seiichi. Sodium content decreased from the first harvest to the second and then increased in the third harvest for all the sites. The concentrations of N increased as the quantity of slurry applied increased.

The mineral element contents were evaluated (Table 5 and 6) according to the dietary requirements of cattle (Grace, 1994; Grace and Clark, 1991; NRC, 1980; Mayland and Shewmaker, 2001). In all the fields, there were adequate amounts of N, S and Cu whereas Zn was less than adequate for cattle dietary requirement. On the other hand, P, K, Ca, Cl, Fe, Mn, Mo, Co and Ni were in more than adequate amounts for cattle dietary requirement. Concentrations of Se and I were also above the dietary requirement and also much higher than the usual concentration in forages.

Interactions and ratios of minerals should be considered when defining requirements for superior livestock health, growth and production. The relative concentrations or ratios of certain mineral nutrients in diets, such as Ca/P and/or K/(Ca+Mg) can affect metabolism or influence the absorption and bioavailability of nutrients (Belesky *et al*., 2001). The K/(Ca+Mg) ratio gradually decreased with increasing number of harvests

Table 4: Digestibility (%) of composite forage mixture of each field in three harvests[1]

		CP		DPP		CFAT		CFIB		ADF		OCW		OCC		OB	
Field	Harvest	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Haruo	1	20.3	19.4	15.4	14.6	4.0	3.0	30.5	30.6	34.0	33.5	54.8	53.7	37.5	31.1	35.6	38.9
	2	21.3	17.2	16.4	12.5	4.6	3.2	27.5	34.2	28.9	35.8	49.3	60.0	39.0	28.8	31.5	44.8
	3	19.9	17.3	15.1	12.6	4.2	4.0	30.0	30.0	29.2	27.3	49.9	52.6	34.2	33.2	36.8	38.7
Seasonal total		61.5	53.9	46.8	39.6	12.8	10.2	88.0	97.7	92.0	96.6	154	166.3	111	93.1	104	122.3
Isao	1	18.6	14.1	13.8	9.9	4.1	3.2	29.0	35.2	32.7	33.7	52.4	60.5	38.3	26.1	33.3	44.5
	2	18.1	13.7	13.3	9.3	4.5	3.4	30.7	39.3	33.3	37.2	55.2	64.5	34.3	24.1	36.5	49.2
	3	14.9	13.8	10.4	9.3	4.0	4.0	36.9	28.0	34.2	25.8	60.7	50.1	25.9	33.8	45.3	38.0
Seasonal total		51.6	41.6	37.5	28.5	12.6	10.6	96.6	102.5	100	96.7	168	175.0	98.4	83.9	115	131.6
Seiichi	1	15.8	16.8	7.0	12.1	2.8	2.7	35.9	34.8	37.0	37.9	62.6	60.9	28.7	27.2	45.8	45.8
	2	14.6	11.5	10.1	8.1	3.3	2.7	32.5	37.3	35.0	37.4	58.7	62.6	31.8	24.7	40.2	49.2
	3	11.2	10.8	11.2	9.3	3.9	3.5	34.4	39.3	31.8	27.6	55.0	52.5	32.1	32.1	38.3	40.3
Seasonal total		41.6	39.0	28.3	29.6	9.9	8.9	103.7	111.4	104	103.0	176	176.0	92.6	83.9	124	135.3

[1]Data average of eight replications

Table 5: Mineral element content of forage mixtures collected from various fields across harvests during 2002[1]

Element	Haruo Harvest 1	Haruo Harvest 2	Haruo Harvest 3	Isao Harvest 1	Isao Harvest 2	Isao Harvest 3	Seiichi Harvest 1	Seiichi Harvest 2	Seiichi Harvest 3	DRC[2]
	$g\ kg^{-1}$									
N	9.7	10.2	9.6	8.9	8.7	7.2	8.4	7.0	7.6	5-10
P	4.1	5.0	3.5	3.2	5.2	4.2	2.6	3.8	3.7	2
K	30.7	36.0	33.0	24.2	30.1	15.7	23.5	26.5	18.1	8
Ca	7.6	7.0	8.6	3.3	4.8	5.2	2.9	3.3	9.3	3-4
Mg	2.8	3.3	3.4	1.9	3.2	3.8	1.2	2.0	3.0	2
S	2.1	1.9	2.2	1.1	1.9	2.1	1.2	1.9	2.1	1-2
Na	0.9	0.3	0.7	1.6	0.2	2.8	1.5	0.5	3.5	2
Si	2.4	4.4	4.4	2.9	3.8	3.6	6.2	10.2	7.5	not established
Cl	4.5	3.7	5.3	8.6	8.2	6.9	12.7	8.4	7.9	2
	$\mu g\ g^{-1}$									
Cu	9.0	11.9	8.8	9.0	12.1	9.5	7.0	9.9	9.0	7-10
Fe	78.6	91.4	81.5	46.8	69.6	71.1	51.4	53.9	73.6	40
Mn	85.1	69.4	66.4	158.5	211.0	289.8	54.4	107.8	113.4	25
Mo	4.7	3.9	2.4	3.3	2.5	1.8	2.4	2.8	2.6	<0.1
Zn	21.4	20.5	22.0	20.3	20.1	27.9	14.3	20.2	22.8	25-40
Co	2.8	1.4	3.5	3.6	3.4	2.6	2.6	4.5	4.8	0.06
I	18.8	61.0	26.7	23.3	69.9	53.1	17.6	27.4	42.3	0.50
Ni	4.6	4.0	4.5	7.2	7.0	7.0	4.5	5.0	5.8	0.06-0.07
Se	3.9	4.9	2.2	1.7	2.1	1.5	3.1	1.7	3.3	0.04-0.30
Mineral interaction[3]										
Ca/P	1.87	1.39	2.45	1.04	0.93	1.23	1.12	0.86	2.53	2
K/(Ca+Mg)	1.28	1.49	1.20	1.91	1.54	0.70	2.48	2.08	0.65	<2.20
Cu/Mo	1.92	3.01	3.73	2.77	4.93	5.40	2.90	3.50	3.42	2-5

[1]Data average of eight replications; [2]DRC = Dietary requirements of cattle (Grace, 1994; Grace and Clark, 1991; NRC, 1980; Mayland and Shewmaker, 2001); [3]Ca/P = Ratio between Ca and P; Cu/Mo = Ratio between Cu and Mo; K/(Ca+Mg) = Computed on a mole equivalent basis

Table 6: Mineral element content of forage mixtures collected from various fields across harvests during 2003[1]

Element	Haruo Harvest 1	Haruo Harvest 2	Haruo Harvest 3	Isao Harvest 1	Isao Harvest 2	Isao Harvest 3	Seiichi Harvest 1	Seiichi Harvest 2	Seiichi Harvest 3	DRC[2]
	$g\ kg^{-1}$									
N	10.8	9.8	9.8	8.3	8.1	8.1	9.5	7.5	8.1	5-10
P	3.3	3.9	3.9	2.6	7.1	4.0	2.1	3.5	5.3	2
K	29.0	32.2	30.9	16.1	18.3	16.4	25.1	28.5	34.2	8
Ca	6.9	2.9	3.9	2.2	2.6	4.7	2.2	3.0	4.8	3-4
Mg	2.1	1.9	2.2	1.8	2.1	2.4	1.3	1.7	2.8	2
S	1.9	1.7	2.0	1.1	1.5	2.1	1.1	1.5	2.6	1-2
Na	0.5	0.2	1.0	3.5	2.7	5.1	1.0	1.0	1.1	2
Si	1.7	7.2	5.5	2.3	9.0	5.0	2.2	11.5	10.9	not established
Cl	9.1	5.7	4.1	10.7	8.8	9.8	13.0	11.6	10.3	2
	$\mu g\ g^{-1}$									
Cu	6.4	8.2	7.4	8.5	8.0	10.5	6.5	12.4	6.2	7-10
Fe	65.1	64.3	85.3	47.6	51.1	75.5	39.9	49.1	82.0	40
Mn	78.8	50.3	47.2	182.9	290.8	236.4	50.1	68.2	147.6	25
Mo	1.8	2.1	2.1	4.1	1.8	2.1	1.3	2.1	4.5	<0.1
Zn	16.1	25.7	31.6	20.3	16.6	25.3	16.0	19.2	22.0	25-40
Co	3.9	4.0	3.0	2.4	4.5	4.5	3.4	4.0	5.8	0.06
I	25.4	17.6	26.3	26.6	25.9	23.6	21.3	28.4	19.6	0..50
Ni	2.7	5.0	5.3	2.5	3.0	8.1	3.6	5.4	1.6	0.06-0.07
Se	3.0	2.4	2.4	2.3	1.1	1.0	2.2	2.4	2.2	0.04-0.30
Mineral interaction[3]										
Ca/P	2.12	0.75	0.99	0.84	0.46	1.17	1.09	0.86	0.90	2
K/(Ca+Mg)	1.43	2.19	2.61	1.62	1.57	0.85	2.93	2.53	1.86	<2.20
Cu/Mo	3.57	3.98	3.50	2.06	4.57	4.93	5.02	5.82	1.38	2-5

[1]Data average of eight replications; [2]DRC = Dietary requirements of cattle (Grace, 1994; Grace and Clark, 1991; NRC, 1980; Mayland and Shewmaker, 2001); [3]Ca/P = Ratio between Ca and P; Cu/Mo = Ratio between Cu and Mo; K/(Ca+Mg) = Computed on a mole equivalent basis

for Isao and Seiichi sites in both 2002 and 2003 (Table 5 and 6). For the Haruo field, the highest K/(Ca+Mg) ratio was found in the second harvest in both years. In the first and second harvests, the critical values for grass tetany potential were exceeded in Seiichi because of the species composition of orchardgrass. Furthermore, Italian ryegrass and Kentucky bluegrass were in higher amounts and also because white clover was not included. The average tetany potential values were below 2.2 in the Isao field in both years. The mean values of K/(Ca+Mg) ratio in the forage mixtures of the three fields from three harvests were less than 2.2 which represents the lower tetany potential. The Ca/P ratios averaged 1.90, 1.07 and 1.50 in 2002 and 1.29, 0.79 and 0.95 in 2003 for the Haruo, Isao and Seiichi fields, respectively. Calcium and P were considered together because of their importance in preventing metabolic function disorders in livestock. Milk fever or parturient paresis is characterized by <1.0 mmol L^{-1} Ca in blood. This problem can occur even when herbage contains 4.4 g Ca kg^{-1} DM. Urinary calculi may occur when diets contain more than twice the dietary P requirement (Emerick, 1988). Maintaining dietary Ca/P ratios in the range of 1.5:2.0 to 2:1 reduces functional disorders related to Ca and P (Underwood, 1966).

CONCLUSIONS

Dry matter production increased as the growing season progressed. This was due to the residual effects of slurry applied as well as the substantially less well-distributed rainfall during the earlier part of the growing seasons. Slurry application positively influenced the yield and nutrient status of forage mixtures. Tetany potential declined substantially as Italian ryegrass and/or Kentucky blue grass in the mixtures was replaced with white clover. The results of this study show that farmers can understand the necessity of adopting legume and grass mixtures and also the application of slurry would enable them to maximize yield as well as maintain high quality forage. Thus, it is important to extend large-scale trials involving grass-legume mixtures with application of slurry over a wide range of sites in different agro-ecological zones in order to establish the effectiveness of the proposed approach. The results of this study could be applied generally at places with comparable conditions as Tanohata namely, low temperature, low precipitation and poor soils. It can be inferred that if farmers adopt the proposed approach, they could save very substantial amounts of N fertilizer in their forage production. Apart from direct N addition to the soil from biological N fixation by forage mixtures, this approach would increase animal manure availability as a result of increase in livestock numbers. The slurry manure would be incorporated into fields to further improve overall N fertility status of soils. Without the adoption of a good grassland management strategy like our proposed approach, soil resources would be at a greater risk from erosion and loss of nutrients and which may finally lead to reduction in cultivable land area.

ACKNOWLEDGMENTS

We are very grateful to Dr. H.F. Mayland (USDA-ARS, Kimberly, Idaho, USA) for kind help during the experiment and Dr. T.A. Adjadeh (Department of Soil Science, University of Ghana, Ghana) for peer review comments on the manuscript. The helps of the Mayor and his staffs of Tanohata Mura are gratefully acknowledged.

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