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Botanical Composition, Herbage Production and Plant Mineral Contents as Affected by Application of Chemical Fertilizer and Fermented Sawdust Pig Manure on Cheju Brown Volcanic Ash Pasture Soil

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Abstract

This experiment was carried out during the period from September, 1997 to October, 1998 to determine the effect of fermented saw-dust pig manure (FSP) application on the herbage production on a mixed pasture in the Cheju brown volcanic ash soil. Split plot design (main plot: 3 nitrogen application levels of 0, 150 and 300 kg/ha; sub plot: 4 pig sawdust manure levels of 0, 3, 6 and 12 ton/ha) was used.

Plant height and dry matter yield increased significantly with an increase of nitrogen and FSP level. There was no difference in the botanical composition of grasses as affected by FSP application level, but herbage yields of grass species were increased by nitrogen application compared to that without nitrogen application. Botanical composition of white clover decreased with an increase of nitrogen application, but increased with an increase of FSP application level.

Percentages of weeds were not affected by application rates of chemical nitrogen fertilizer and swine manure in the mixed species pasture. Nitrogen, phosphorus, and potassium contents of species in the pasture significantly increased with increasing application rates of nitrogen fertilizer. In conclusion, it would be an optimum to apply 150 kg/ha of inorganic chemical fertilizer and plus either 3 or 6 ton/ha of fermented swine manure with sawdust for optimum production of mixed pasture on Cheju Island.

(**Key words** : Herbage production, Botanical composition, Morphology, Plant mineral contents)

I. Introduction

Cheju Island has an optimum climate as well as available roughage for cattle in mid-mountain areas giving it many advantages in forage-livestock production over other locations in South Korea. However, the soil type on Cheju Island is an infertile volcanic soil that has pH 5.0~5.3, organic matter 7.8~19.0%, and P_2O_5 20~30 ppm (Lee and Lee, 1975). Because applying chemical fertilizer to forages is not economical due to increase in chemical fertilizer costs, many livestock producers do not utilize the grassland efficiently.

Swine production on Cheju Island is the second greatest income source after orange farming. However, it has become a serious social issue in terms of utilizing and disposing of hog manure. If the swine manure was utilized as a valuable fertilizer for crops, it could both contribute to produce high quality forages and save on chemical fertilizer costs. Cho (1994) reported that 30 ton/ha of poultry litter composted with sawdust and 30 ton/ha of cattle manure composted with sawdust could reduce the chemical fertilizer use by 75 and 42 kg per hectare, respectively. Cattle manure application at the rate of 20 ton/ha produced 8 %

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more dry matter yield than chemical fertilizer application and optimum application rate of swine manure composted with sawdust was 30 ton/ha in the field of Agricultural Improvement Institute, Choongnam province (Cho, 1994). Song et al. (1994) also reported that an optimum rate of dried swine manure for forage crop production was 20 ton/ha in the eastern part of Japan. Herbage yield in the pasture significantly increased with increasing nitrogen rate from manure with the addition of 100 kg/ha of urea, but yield decreased with the addition of 200 kg/ha of urea plus 160 kg/ha of manure (Cheong et al., 1993). However, no experiment, however, was done in Cheju volcanic soil to determine the efficiency of composted swine manure fermented with sawdust. The objective of this study was to investigate the effects of swine manure fermented with sawdust and chemical nitrogen fertilizer applications on herbage yield, mineral content of the forages, chemical and physical properties of the soil, and the microbial population in pasture soils.

II. Materials and Methods

1. Experimental period and location

This experiment was conducted at the test pasture field having orchardgrass (25 kg/ha), perennial ryegrass (10 kg/ha), and white clover (3 kg/ha) in Cheju National University from September 1997 to October 1998. Chemical characteristics of the soil used are shown in Table 1 and relatively infertile soil. The experimental design was randomized complete block with split block design and 200 kg/ha of phosphate and 150 kg /ha of potash were applied (Table 2). One third of phosphate and potash was applied before planting and two thirds were applied equally in May, June, and September and composition of fermented sawdust swine manure is shown in Table 3.

Forage was harvested from 1m^2 (1m × 1m) and 100 g of sub-samples was dried at 65℃. Composition of grasses was separated and converted to percentage by multiplying 100. Mineral contents of forage were analyzed using Yoshidas method (1983). Phosphorus was measured using a U/V spectrophotometer and other minerals K, Ca, Mg, Na, Cu, Co, and Zn were analyzed using a atomic absorption spectrophotometer (Perkin-Elmer Corpoation, 1982).

As one of the morphological characteristics, plants were collected from two locations using a soil core of 15 cm diameter, washed with water, separated by species, and growing points were counted. Data were analyzed using a Statistix program and means were compared using an LSD test if there was a significant difference with an alpha level of 0.05.

Table 1. Chemical characteristics of the soil

pH (1:5)	OM (%)	N (%)	P_2O_5 (ppm)	Exchangeable cation (cmol$^+$/kg)				Permeable speed (cm/sec)	Bulk density	Water content (%)
				K	Ca	Mg	Na			
5.23	7.54	0.22	7.56	0.62	0.22	0.41	0.27	0.10	2.42	48.4

Table 2. Experiment design

Main plot (nitrogen application, kg/ha)	Sub plot (pig manure application, ton /ha)
0	0
150	3
300	6
	12

Table 3. Composition of fermented saw-dust pig manure used

Water content	OM	T-N	K_2O	CaO	MgO	P_2O_5	Cd	Pb	Hg	As
%	%	%	%	%	%	·········	ppm	·········	······ ppb	······
15.56	46.46	2.05	1.23	8.83	1.41	2.93	1.70	1.70	38.0	ND

* ND: not detected.

III. Results and Discussion

1. Dry matter yield

Herbage yields of mixture from the chemical nitrogen application were shown in Table 4 and herbage yields at the 0, 150, and 300 kg N/ha were 7,715, 11,574, and 11,709 kg/ha ($p<0.05$). These results were similar to reports of Kim and Kang (1991), Wilman and Holington (1985), and Sollenberger et al. (1984). Although Kim (1991) reported that 200 kg N/ha was an optimum for single species pasture production, 150 kg N/ha appears to be an optimum rate in this study. This is in agreement with reports of Nielson and Steffens (1994) where optimum nitrogen rate for crop production was 150 kg/ha in Germany.

There was significant yield ($p<0.05$) increase of 9,935, 10,768, and 10,292, and 10,335 kg/ha from the application of 0, 3, 6, and 12 ton/ha, respectively of fermented swine manure. Wolton (1963) reported that herbage yield of grasses increased with increasing rates of manure application, which was in agreement with this study, however there was no significant increase in legumes. Herbage yield of reed canarygrass was higher than ryegrass with applying liquid manure (Studdy et al., 1995). Yoo et al. (1992) reported that dry matter yield of silage corn was not increased with increasing rates of cattle or swine manure. This indicates that the effectiveness of crops to utilize manure nutrients can be varied with different environments. According to Nielson and Steffens (1994) in Germany, nutrient requirements of general crops were 150~90 150 kg of N, P, and K per hectare and when animal manure was utilized, 150 ton/ha was required to produce an optimum yield. When supplemental nitrogen application was needed from the animal manure application, Ernst (1985) reported that 300 kg total N/ha was an optimum rate whereas Corrie and Dijkmann (1988) reported that herbage dry matter yield increased up to 450 kg/ha. Total nitrogen of fermented swine manure used in this study was 2.05% and nitrogen yields of 3, 6, and 12 ton were 52, 104, and 209 kg, respectively. Therefore, 150 kg/ha of chemical fertilizer plus 3 ton fermented swine manure (total 202 kg total N/ha) appears to be enough for nitrogen requirement of forage crops utilized in this study.

Although 12 tons per hectare of swine manure had 208 kg N/ha which is enough for crop

Table 4. Dry matter yield of mixed pasture as affected by nitrogen and fermented saw-dust manure application rates (kg/ha)

Nitrogen level (kg/ha)	Swine manure levels(ton/ha) 0	3	6	12	Mean
0	7,890	7,630	7,850	7,490	7,715^{b}
150	11,100	12,885	10,895	11,415	11,574^{a}
300	10,815	11,790	12,130	12,100	11,709^{a}
Mean	9,935^{b}	10,768^{a}	10,292^{ab}	10,335^{ab}	

* ^{a,b} : Means not sharing the same superscript letters are different(P<0.05).

production, herbage yield at the 12 tons was significantly lower than the combination of 150 kg N/ha and 3 tons of fermented swine manure with sawdust. This was similar to those of Sikora and Azam (1993). In this study, 250 kg N/ha appears to be an optimum rate for mixed pasture production and applying both inorganic fertilizer and fermented swine manure with sawdust would desirable practice rather than either inorganic fertilizer or swine manure itself. Based on this, it would be an optimum to apply 150 kg/h of inorganic chemical fertilizer and plus either 3 or 6 ton/ha of fermented swine manure with sawdust for optimum production of mixed pasture on Cheju Island.

2. Botanical composition

As shown in Fig. 1, percentage of grasses increased with increasing application rates of chemical nitrogen fertilizer except the no manure application treatment. This was in agreement with reports of Kim and Kang (1991), Jin et al. (1980), and Losper et al. (1967) where percentages of grasses increased as nitrogen application rates.

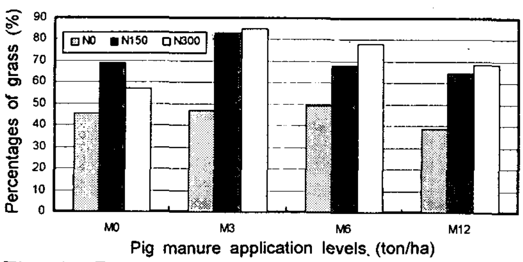

Fig 1. Percentage of grasses in the pastures as affected by nitrogen and swine manure application rates.

Application of swine manure fermented with sawdust did not affect the botanical composition in the legume-grass mixed pasture. This result was similar to Kim et al.s report (1991) that percentages of grasses in the legume-grass mixed pasture were not affected by liquid manure application.

Percentages of white clover increased with increasing application rates of swine manure fermented with sawdust whereas decreased with increasing application rates of chemical nitrogen fertilizer. This fact was consistent with other researches (Klapp, 1991; Voigtlander and Jacob, 1987; Kim and Kang, 1991). The reasons why the percentages of white clover increased with increasing rates of swine manure fermented with sawdust appear that white clover might have utilized more phosphorus and potassium efficiently than orchard-grass as application rates of swine manure increased. This was different from the research reporting that there was no difference in percentage of legumes between nitrogen fertilizer and animal manure (Wightman et al., 1997).

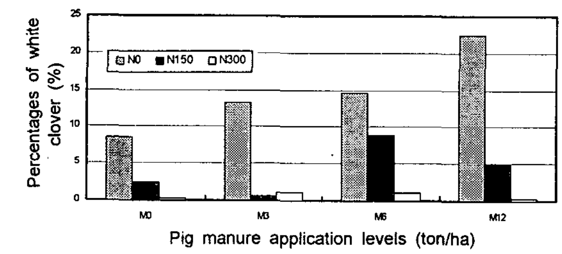

Fig 2. Percentage of white clover in the pastures as affected by nitrogen and swine manure application rates.

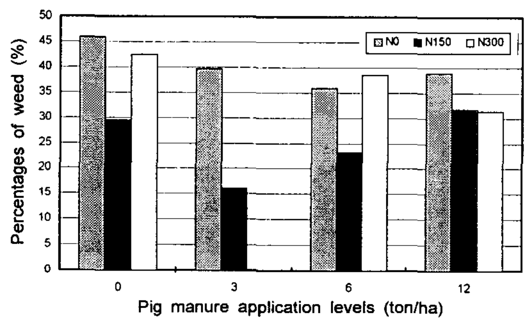

Fig 3. Percentage of weeds in the pastures as affected by nitrogen and swine manure application rates.

Percentages of weeds were not affected by application rates of chemical nitrogen fertilizer and swine manure in the mixed species pasture (Fig. 3). Zurn (1968) reported that optimum percentage of grasses in the mixed species pasture was 65~75%, however, in this study percentage of grasses was only 30~45% which was much lower than the optimum percentage of grasses in the pasture. This was most likely due to higher rates of weeds that were germinated later and gave detrimental effects on establishment of grasses in the pasture. In addition, low soil pH (5.23) at the beginning stage of experiment appears to contribute to the growth of weeds that were tolerant of low soil pH.

3. Morphological characteristics of forage species

Numbers of growing points in grasses increased with increasing application rates of chemical nitrogen fertilizer without applying swine manure whereas the 12 ton/ha of swine manure fermented with sawdust decreased numbers of growing points (Table 5). There were no consistent results at the 3 and 6 ton/ha of swine manure treatments. Numbers of growing points in white clover were significantly affected by application rates of nitrogen fertilizer and swine manure fermented with sawdust. However, numbers of growing points in white clover decreased with increasing application rates of chemical fertilizer. At no fertilizer treatment, numbers of growing points in white clover increased with increasing application rates of swine manure. In contrast, numbers of growing points in white clover increased with applying 150 kg/ha of nitrogen fertilizer with the addition of 6 ton/ha of swine manure and decreased at the rate of 12 ton/ha of swine manure. At the 300 kg/ha of chemical fertilizer treatment, numbers of growing points in white clover were greater at the 0 and 12 ton/ha of swine manure than the 3 and 6 ton/ha of swine manure. In other words, numbers of growing points can be reduced if nitrogen fertilizer is applied none or too much for white clover.

4. Mineral contents of pasture species

Nitrogen, phosphorus, and potassium contents of species in the pasture significantly increased ($p < 0.05$) with increasing application rates of nitrogen fertilizer (Table 6). This was consistent with the reports of Kim (1991), Wilman (1980), Wilman and Hollington (1985), and Gaborik (1989). In contrast, nitrogen content significantly decreased ($p<0.01$) with increasing application rates of swine manure fermented with sawdust. However, Shin (1999) reported that nitrogen content of forage species significantly increased with increasing application rates of liquid type of cattle or swine manure.

Table 5. Growth point numbers of orchardgrass and white clover as affected by nitrogen and pig manure application level

Nitrogen level	Pig manure level (ton/ha)					
	0	3	6	12	SE	Mean
Orchardgrass						
N-0	1.72	1.34	1.42	3.49	0.51	1.99
N-150	3.48	2.57	2.90	2.40	0.24	2.84
N-300	5.22	1.91	1.98	1.81	0.83	2.73
SE	1.01	0.36	0.43	0.49		0.27
Mean	3.47	1.94	2.10	2.56		2.52
White Clover						
N-0	1.50	2.22	2.36	2.44	0.20	2.15
N-150	0.39	0.34	1.68	1.35	0.34	0.94
N-300	0.27	0.67	0.57	0.10	0.13	0.40
SE	0.41	0.58	0.52	0.68		0.52
Mean	0.74	1.08	1.53	1.30		1.16

Table 6. Mineral content of pasture species harvested on April 11 as affected by nitrogen and swine manure application

Item	N	P	K	Ca	Mg	Ca/P	K/(Ca+Mg)
	………… mg/g …………						
Nitrogen rates (kg/ha)							
0	19.5 [c]	12.20 [b]	29.92 [c]	3.21	3.07	0.26 [a]	1.940
150	25.0 [b]	14.36 [a]	32.29 [b]	3.01	2.98	0.21 [a]	2.117
300	29.5 [a]	15.22 [a]	38.77 [a]	2.99	3.64	0.20 [a]	2.283
Swine manure rates (ton/ha)							
0	26.9 [a]	13.60	27.51	3.40	3.33	0.24 [a]	2.004
3	26.4 [a]	15.64	28.37	3.71	3.54	0.24 [a]	1.958
6	25.2 [a]	13.92	27.29	2.66	3.10	0.20 [a]	2.419
12	22.0 [b]	13.40	26.34	2.88	3.14	0.22 [a]	2.074

[a, b, c]: Means in the same column not sharing the same superscripts differ($P<0.05$).

Table 7. Mineral content of pasture species harvested on October 24 as affected by nitrogen and swine manure application

Item	N	P	K	Ca	Mg	Ca/P	K/(Ca+Mg)
	………… mg/g …………						
Nitrogen rates (kg/ha)							
0	27.6 [b]	10.49	15.77	2.57	2.97	0.24	0.135
150	29.7 [a]	9.57	15.54	2.84	3.43	0.29	0.948
300	30.9 [a]	9.62	16.27	2.30	3.22	0.24	1.138
Swine manure rates (ton/ha)							
0	30.2	10.47	16.72	2.91	3.26	0.27	1.033
3	29.3	9.24	14.95	2.61	3.29	0.28	0.990
6	29.1	10.23	17.93	2.59	3.23	0.25	1.229
12	30.4	9.39	14.92	2.23	3.22	0.24	1.042

[a, b] : Means in the same line with different superscripts differ($P<0.05$).

Phosphorus content of plants increased with increasing application rates of chemical nitrogen fertilizer and this was in agreement with Whiteheads results (1970). Gonzalez and Sanchez (1989), however, reported that phosphorus content of forage species decreased with increasing nitrogen application rates and this indicates that different results can be achieved by different soil phosphorus levels and climatic conditions.

Potassium content also increased with increasing application rates of chemical nitrogen fertilizer, which was consistent with the results of Peny et al. (1980), Grunes et al. (1985), and Ebelhar et al. (1987). Kim (1991) reported that potassium content of forage decreased with increasing nitrogen application rates at no potassium application treatment and increased at the 200 kg N/ha, indicating that different soil potassium levels could change the potassium contents of plants. No significant difference was found in potassium contents of plant species in the pasture by applying swine manure fermented with sawdust. This different result might be due to the experiment design that generally had lower application rates of swine manure fermented with sawdust.

Mineral contents of forage species in the pasture harvested in October, 1998 were shown in table 7. Only nitrogen content significantly increased with increasing application rates of nitrogen fertilizer and other mineral contents were not affected. Increasing application rates of swine manure fermented with sawdust did not affect mineral contents of forage species in the pasture. The reason for not showing significant difference from the application of chemical fertilizer and swine manure was most likely due to poor growth of pasture species resulting from lower precipitation during October, 1998.

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