J. Korean Grassl. Sci. Vol. 20(2) : 139~146, 2000

Physical, Chemical Properties and Microbial Population of Soil as Affected by Application of Chemical Fertilizer and Swine Manure Fermented with Sawdust on Cheju Brown Volcanic Ash Pasture Soil

Moon-Chul Kim, Hae-Nam Hyun, and Sung-Cheol Lee*

Abstract

A trial was carried out to investigate the effect of fermented saw-dust pig manure (FSP) and N fertilizer application on physical, chemical properties and microbial population of soil on Cheju brown volcanic ash pasture during the period from September, 1997 to January, 1999. Average soil N contents during 3 different periods, August and October, 1998, and January, 1999 were 0.39, 0.41 and 0.39% for fertilizer N level 0, 150 and 300kg/ha, respectively. Soil N contents determined in January, 1999, was significantly increased by an increase of fertilizer N. Nitrogen contents in the soil applied with 0, 3, 6 and 12 tons / ha of FSP were 0.43, 0.40, 0.38 and 0.38%, respectively, showing decreasing tendency of soil with increasing levels of FSP application. Soil N contents determined in August, 1998 and January, 1999, were significantly decreased by increasing levels of FSP application. Organic matter contents of the soil applied with N 0, 150 and 300 kg/ha was 8.04, 8.37, and 9.08%. Soil organic matters determined on the 1st and 2nd period trended to increase with increasing level of fertilizer N. FSP application significantly decreased organic matter contents of pasture soil, (9.14, 8.79, 8.28 and 7.78% OM in soil applied with FSP 0, 3, 6 and 12 ton/ha of FSP), respectively. Soil OM determined in October, 1998, also showed a significant decrease with increasing level of FSP. Soil pH, available phosphorus, exchangeable K, Ca, Mg and Na in pasture soil studied were not influenced by fertilizer N or FSP application during all three periods. N application tended to increase soil bacteria count, (27.0×10^4 cfu/g, 29.4×10^4 cfu/g and $53.6\ 10^4$ cfu/g in the soil applied with 0, 150 and 300 kg N/ha, respectively). The number of colonies of soil bacteria and fungi determined in June and October, 1998 was not increased remarkably by FSP application, but the number of colonies of bacteria determined in March, 1998 showed a significant increase with increasing level of FSP application. In conclusion, N contents and OM of soil increased with increasing level of N application, but decreased with increasing level of FSP application.

(Key words : Soil physical and chemical properties, Soil microbiology)

I. Introduction

The soil type at the mid-mountain areas on Cheju Island is a brown volcanic ash pasture soil. This soil has therefore a very low cation exchange capacity (CEC) and orthophosphate content whereas high capability of phosphate fixation (Lee and Lee, 1975). They ascertained that a low soil quality of pasture soil could be improved by efficient utilization of liming, superphosphate fertilization, and

College of Agriculture, Cheju National University, Cheju 690-756, Korea
* Dept. of Animal Science, WooSuk University, Wanju, 565-800. Korea

organic matter.

Although swine operation is ranked as the second highest income source among the first industries, manure utilization / disposal is a really big issue on Cheju Island. However, if swine manure can be efficiently utilized on the pasture as a valuable fertilizer, the soil quality could be improved. Effectiveness of animal manure was already proved by many researchers. Soil organic matter and total nitrogen increased with increasing the application rates of composting materials whereas soil bulk density and carbon to nitrogen ratio (C/N) decreased (Sommerfeldt and Chang, 1987). Pocknee and Sumner (1997) reported that soil pH can be changed by conditions of organic matters utilized and contents of N and Ca in organic matter.

Breakdown of organic matter in the soil can be changed by adding plant residues (Bingeman et al., 1953) whereas Broadbent (1947) reported that breakdown of organic matter can be either stimulated or reduced. Sikora and Yakovchenko (1996) reported that effectiveness of composting application and contents of soil organic matter at the infertile soils whereas was high at the fertile soils.

Activity of beneficial soil microorganisms increased with the application of organic matters (Agriculture and Fisheries Organization, 1988) and biomass carbon of Cheju Island soil was higher at the volcanic soil than at the non-volcanic soil and higher in August than in September (Oh, 1982). In the tea cultivation fields, numbers of soil bacteria, actinomycetes, and fungi were affected by the levels of C/N ratio in the soil (Pansombat et al., 1997). This study was conducted to determine the application effects of swine manure fermented with sawdust and chemical nitrogen fertilizer on physical, chemical properties, and microbial population of soil on Cheju brown volcanic ash pasture.

II. Materials and Methods

This study was conducted at the test field of Cheju brown volcanic ash pasture from September, 1997 to October, 1998. Soil physical- and chemical properties of test field before the initiation of the experiment is shown at Table 1 and characteristics of swine manure fermented with sawdust is shown at Table 2. Soil physical- and chemical properties were analyzed using soil analysis methods developed by Korean Farm Improvement Institute (1988). Forage samples were digested using a micro Kjeldahl for nitrogen content and ammonia was calculated by a spectrophotometer (AOAC, 1984; Weatherbum, 1967).

Soil samples were taken to determine the effects of various application rates of swine manure fermented with sawdust on soil microbial populations and organic matter in the spring, summer, and fall. Soil microbial populations were measured after cultivation at 28℃ by a dilution method (Soil

Table 1. Characteristics of soil before the experiment

pH (1:5)	OM (%)	N (%)	P_2O_5 (ppm)	Cation exchangeable capacity (cmol/kg)				Permeable speed (cm/sec)	Bulk density (g/cm^3)	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. Fertility of fermented saw-dust pig manure examined

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

Microbial Research Association, 1982). Microbial populations were expressed as a colony forming unit (CFU). Yeast glucose agar (yeast extract 3, glucose 1, K_2HPO_4 0.3, KH_2PO_4 0.2, $MgSO_4 \cdot H_2O$ 0.2, cyclohexamide 0.05, agar 15 g, and distilled water 1,000 ml) and Rose bengal agar (KH_2PO_4 1, $MgSO_4 \cdot 7H_2O$ 0.5, peptone 5, glucose 10, rose bengal 0.033, streptomycin sulfate 0.033, agar 20 g, and distilled water 1,000 ml) were used to culture bacteria and fungus, respectively.

The experimental design was a split plot with a randomized complete block design and the whole plot was three application rates of nitrogen (0, 150, and 300 kg/ha) and the sub-plot was four application rates of swine manure fermented with sawdust (0, 3, 6, and 12 ton/ha). 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.

Ⅲ. Results and Discussion

1. Soil Nitrogen

Soil nitrogen from the chemical fertilizer and composted swine manure fermented with sawdust is shown in Fig. 1. Soil nitrogen in the second year of pasture production increased with increasing application rates of nitrogen fertilizer, however there was no significant difference ($p>0.05$). In the third production year, soil nitrogen significantly increased with increasing the application rates of chemical nitrogen fertilizer. These results were similar to the reports of Jelhum et al. (1995) and Gao and Chang (1996) where soil inorganic nitrogen content increased with increasing the application rates of composts. However, no significant difference was found in soil nitrogen with applying chemical nitrogen fertilizer 0, 150, and 300 kg/ha ($p>0.05$). Soil nitrogen rather decreased with applying chemical nitrogen fertilizer in the second year of pasture production.

Although plant height and herbage dry matter yield were directly affected by nitrogen fertilization, oil nitrogen levels were not affected since soil type of test field was silt loam and infiltration rate was 10 cm/sec that was really fast enough to be leached as nitrate. Soil nitrogen levels at the 0, 3, 6, and 12 ton/ha of fermented swine manure with sawdust were 0.43, 0.40, 0.38, and 0.38%, respectively. Although no significant difference was found between treatments, there was a decreasing tendency in soil nitrogen with increasing application rates of swine manure. Soil nitrogen decreased with increasing application rates of swine manure fermented with sawdust in August, 1998 and January, 1999. This trend was same when the soil

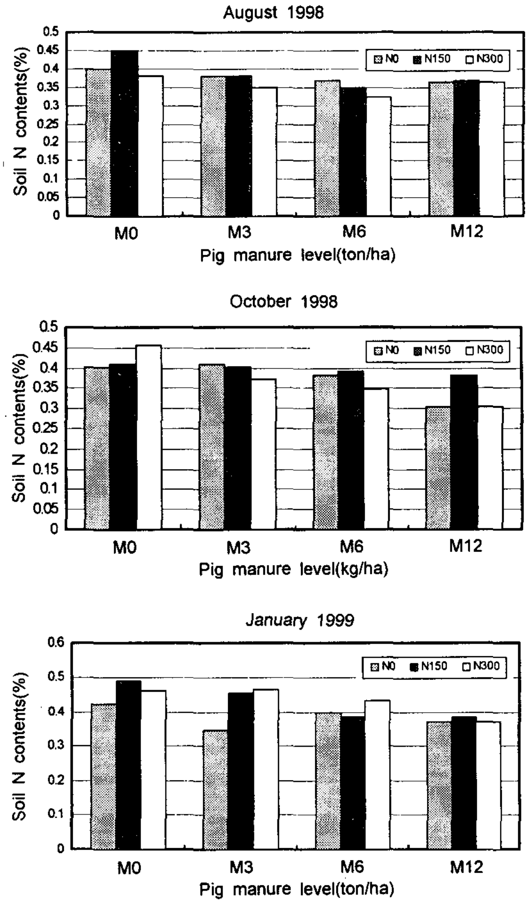

Fig 1. Soil N content of the pasture as affected by N fertilizer and swine manure application rates.

nitrogen was measured in October, 1998, but there was no significant difference. Sikora and Yakovenko (1996) reported that the effectiveness of animal manure application to the crop field was very high in low fertility soils whereas it was opposite in the high fertility soils. Since the test field has been fertilized with chemical fertilizer since 1995, soil appears to be fertile and therefore the effects of swine manure fermented with sawdust on soil nitrogen was minimal.

2. Soil Organic Matter

Soil organic matter was significantly increased ($p < 0.01$) from 8.04 to 9.08% with increasing rates of chemical nitrogen fertilizer from 0 to 300 kg/ha. At the first and third examination, soil organic matter increased with increasing application rates of nitrogen fertilizer (Fig. 2). This was a different phenomenon from the general non-volcanic soil. It appears that soil organic matter increased with increasing plant height, dry matter, and at the same time good growth under the ground and dead roots accumulated in the soil, resulting from increasing application rates of nitrogen fertilizer.

As well, soil organic matter significantly decreased ($p < 0.01$) from 9.14 to 7.78% with increasing application rates of swine manure fermented with sawdust from 0 to 12 tons/ha. Even at the second examination in late October, 1998, soil organic matter content significantly decreased with increasing application rates of swine manure fermented sawdust. This was not in agreement with results of Sommerfeldt (1998) where soil organic matter increased with increasing application rates of animal manure. Bingeman et al. (1953) reported that breakdown rates of soil organic matter could be changed by adding plant residues into the soil whereas Broadbent (1947) mentioned that breakdown of organic matter could be either stimulated or lowered by plant residues. Sikora and Yakovchenko (1996) reported that efficiency of compost was higher at the low fertility soil whereas soil organic

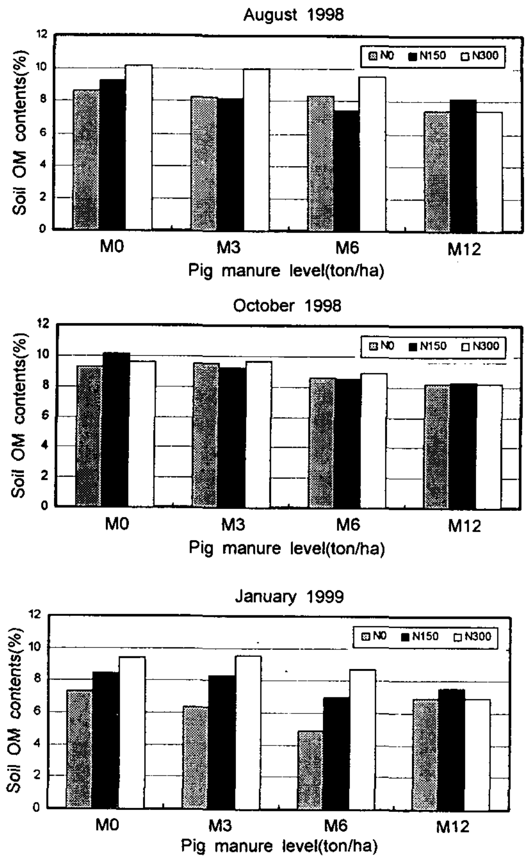

Fig 2. Soil organic matter(OM) content of the pasture as affected by N fertilizer and swine manure application rates.

matter did not increase with increasing application rates of compost. In this study, soil organic matter content increased only by 0.6% with injecting 12 ton/ha of swine manure fermented with sawdust having 50% organic matter into the soil depth of 10 cm. In contrast, soil organic matter content before the initiation of the experiment was high enough to be 7.5% and therefore the effectiveness of swine manure fermented with sawdust was not that significant.

3. Chemical characteristics of pasture soil

As shown in Table 3, soil inorganics; P, K, Ca, Mg, and Na were not affected by chemical N

Table 3. Changes in chemical characteristics of the soil as affected by the nitrogen application

		Nitrogen application rate(kgN/ha)				
		0	150	300	Mean	Significance
P	1st	18.36	60.50	23.22	34.03	NS
	2nd	39.93	49.32	32.71	40.65	NS
	3rd	15.72	41.67	18.73	25.37	NS
	mean	24.67	50.50	24.89	33.35	
K	1st	0.91	0.99	0.58	0.83	NS
	2nd	0.70	0.52	0.52	0.58	NS
	3rd	0.55	0.66	0.64	0.62	NS
	mean	0.72	0.72	0.58	0.68	
Ca	1st	0.42	1.11	0.51	0.68	NS
	2nd	1.19	1.48	0.89	1.19	NS
	3rd	1.07	2.16	0.84	1.36	NS
	mean	0.89	1.58	0.75	1.08	
Mg	1st	0.78	1.96	0.81	1.18	NS
	2nd	1.70	1.84	1.30	1.81	NS
	3rd	1.44	2.69	1.49	1.87	NS
	mean	1.31	2.16	1.20	1.62	
Na	1st	0.30	0.30	0.25	0.26	NS
	2nd	0.20	0.20	0.19	0.20	NS
	3rd	0.22	0.22	0.21	0.21	NS
	mean	0.24	0.24	0.22	0.22	
pH	2nd	5.64	5.66	5.52	5.61	NS

NS : not significant,
1st : Spring(11 April)
2nd : Surnmer(20 June)
3rd : Autumn(24 Oct)

fertilization. This was most likely that some of nitrogen from N fertilization must have either utilized or leached since soil sampling was taken from the second year after seeding. Soil P, K, Ca, Mg, and Na also were not affected by the application rates of swine manure fermented with sawdust. Soil pH was not affected by increasing application rates of swine manure fermented with sawdust from 0 to 12 ton/ha when soil sampling was done in June, 1998. There are two different groups saying that soil pH was either increased (Ashgar and Kanehiro, 1980; Bessho and Bell, 1992; Tyson and Cabrera, 1993) or decreased (Robertson et al., 1982; Tyson and Cabrera, 1993; Bevacqua and Mellano, 1994) by applying organic materials. Soil pH can be changed by conditions of organic materials applied. Pocknee and Sumner (1997) reported that soil pH was changed by the contents of N and Ca in organic materials. In this study, however, soil pH was not affected by application rates of swine manure fermented with sawdust. This might be due to short time period after manure application to the soil for microbial activity.

4. Soil microbial population

Although the number of bacteria population tended to increase (27.0, 29.4, and 53.6 $\times$ 10^4 cfu/g) with

Table 4. Changes in chemical characteristics of pasture soil as affected by swine manure application

		Swine manure rate(kgN/ha)					
		0	3	6	12	Mean	Significance
P	1st	74.34	21.29	14.15	25.71	33.87	NS
	2nd	46.00	59.57	26.03	31.12	40.68	NS
	3rd	29.15	34.23	22.67	17.18	25.81	NS
	mean	49.83	38.36	20.95	24.67	33.45	
K	1st	1.29	0.68	0.78	0.60	0.84	NS
	2nd	0.52	0.73	0.47	0.53	0.56	NS
	3rd	0.52	0.74	0.62	0.61	0.62	NS
	mean	0.78	0.72	0.62	0.58	0.67	
Ca	1st	1.24	0.49	0.50	0.60	0.71	NS
	2nd	1.40	1.23	0.94	0.94	1.13	NS
	3rd	1.61	1.72	1.01	1.08	1.36	NS
	mean	1.42	1.15	0.82	0.87	1.07	
Mg	1st	2.23	0.80	0.90	0.94	1.22	NS
	2nd	1.77	1.86	1.22	1.52	1.58	NS
	3rd	2.10	2.10	1.67	1.74	1.90	NS
	mean	2.03	1.59	1.26	1.40	1.57	
Na	1st	0.30	0.25	0.25	0.25	0.26	NS
	2nd	0.20	0.19	0.20	0.20	0.20	NS
	3rd	0.22	0.21	0.20	0.21	0.21	NS
	mean	0.24	0.22	0.22	0.22	0.22	
pH	2nd	5.84	5.69	5.52	5.64	5.68	NS

increasing application rates of nitrogen fertilizer (0, 150, and 300 kg/ha), there was no significant difference in March, June, and October. There was also no significant difference in fungi population with increasing chemical nitrogen fertilizer. These results were not consistent with other studies where microbial population increased with increasing the application rates of nitrogen fertilizer (Won et al., 1999, Beck, 1975, Martyniuk and Wagner, 1978, and Nishio and Kusano, 1980).

There was no significant difference in microbial population with varying application rates of composted swine manure fermented with sawdust in June and October, but there was significant difference ($p<0.05$) in March. This was in agreement with Won's et al's (1999) research where application of swine manure increased microbial population in cabbage production. It is uncertain why bacteria population increased in March, 1998. Heavy rainfall (228 mm) in June might have destroyed the ecosystem of microbial population.

Based on the results mentioned above, soil nitrogen and organic matter increased with increasing application rates of nitrogen fertilizer at the Cheju brown volcanic ash pasture soil whereas decreased with composted swine manure fermented with sawdust. It appears that a year period of experiment was not enough to have more obvious results from the composted swine manure fermented with sawdust since organic material needs to be mineralized.

Table 5. The number of microbial population in soil as affected by nitrogen fertilizer and swine manure application($\times 10^4$cfu/g)

Treatment		Bacteria				Fungi			
		3/12	6/10	10/24	mean	3/12	6/10	10/24	mean
N_0M_0		33.33	10.33	36.33	26.66	2.00	2.33	4.00	2.78
N_0M_3		39.00	13.33	36.33	29.55	8.67	5.00	8.67	7.45
N_0M_6		41.33	6.00	14.50	20.61	1.37	2.33	6.33	3.34
N_0M_{12}		18.33	10.00	62.33	30.22	1.70	1.33	6.67	3.23
mean		33.00	10.67	37.37	26.76	3.44	2.75	6.42	4.20
$N_{150}M_0$		20.00	9.00	42.33	23.78	1.70	3.67	2.67	2.68
$N_{150}M_3$		27.00	7.67	69.33	34.67	1.03	3.67	5.33	3.34
$N_{150}M_6$		55.33	11.00	24.33	30.22	2.70	7.67	5.33	5.23
$N_{150}M_{12}$		31.67	24.33	45.00	33.67	1.32	8.67	5.67	5.22
mean		33.50	13.00	42.25	29.58	1.69	5.92	4.75	4.12
$N_{300}M_0$		35.00	77.00	36.67	49.56	1.33	8.33	2.00	3.89
$N_{300}M_3$		91.33	18.00	77.00	62.11	3.00	3.00	2.67	2.89
$N_{300}M_6$		93.00	13.00	32.33	46.11	2.00	7.67	2.00	3.89
$N_{300}M_{12}$		49.00	49.00	71.33	56.44	1.03	9.67	3.00	4.57
mean		67.08	39.25	54.33	53.55	1.84	7.17	2.42	3.81
	Main(A)	0.076	0.118	0.586		0.306	0.116	0.113	
P	Sub(B)	0.022	0.263	0.609		0.174	0.662	0.558	
	A×B	0.357	0.214	0.343		0.421	0.567	0.849	

* P : probability.

IV. References

1. A.O.A.C. 1984. Official methods of analysis 14th ed. (Ed. S. Williams). AOAC, Arlington. VA.
2. Ashgar, M., and Y. Kanehiro. 1980. Effects of sugar cane trash and pineapple residue on soil pH, redox potential, extractable Al, Fe, and Mn. Trop. Agric. (Trinidad) 57:245-258.
3. Beck T. 1975. Effects of extended monoculture and rotation crop systems on microbiological activities in soil and soil organic matter. Transaction of the International Symposium. Prague. Humus et plant. VI. 407-414.
4. Bessho, T., and L.C. Bell. 1992. Soil solid and solution phase changes and mung bean response during amelioration of aluminium toxicity with organic matter. Plant Soil 140:183-196.
5. Bevacqua, R.F., and V. J. Mellano. 1994. Cumulative effects of sludge compost on crop yield and soil properties. Commun. Soil Sci. Plant Anal. 25:395-406.
6. Bingeman, C. W., J. E. Warner, and W. P. Martin. 1953. The effect of the addition of organic materials on the decomposition of an organic soil. Soil Sci. Soc. Am. Proc. 17:34-38.
7. Broadbent, F.E. 1947. Nitrogen release and carbon loss from soil organic matter during decomposition of added plant residues. Soil Sci. Soc. Am. Proc. 12:246-249.
8. Gao, G., and C. Chang 1996. Changes in CEC and particles size distribution of soils associated with long-term annual applications of cattle feedlot manure. Soil Sci. 161:115-120.
9. Jellum, E. J., S. Kuo, and Sainju. 1995. Mineralization and plant availability of nitrogen

in sea food waste composts in soil. Soil Sci. 160:125-135.

10. Martyniuk, S., and Wagner, G.H. 1978. Quantitative and Qualitative examination of soil microflora associated with different management system. Soil Sci. 125:343-350.
11. Nishio, M., and S. Kusano. 1980. Fluctuation patterns of microbial numbers in soil applied with compost. Soil Sci. Plant Nutri. 26(4):581-593.
12. Pansombat, K., S. Kanazawa, and T. Horiguchi. 1997. Microbial ecology in tea soils. I. Soil properties and microbial populations. Soil Sci. Plant Nutr., 43(2):317-327.
13. Pocknee S., and M.E. Sumner. 1997. Cation and nitrogen contents of organic matter determine its soil liming potential. Soil Sci. Soc. Am. J. 61:86-92.
14. Robertson, W.K., M.C. Lutrick, and T.L. Yuan. 1982. Heavy applications of liquid-digestted sludge on three Ultisols: I. Effects on soil chemistry. J. Environ. Qual. 11:278-282.
15. Sikora, L.J., and Yakovchenko. 1996. Soil organic matter mineralization after compost amendment. Soil Sci. Soc. Am. J. 60:1401-1404.
16. Sommerfeldt, T.G., and C. Chang. 1987. Soil-water properties as affected by twelve annual application of cattle feedlot manure. Soil Sci. Soc. Am. J. 51:7-9.
17. Somerfeldt, T.G., C. Chang, and T. Entz. 1988. Long-term annual manure applications increase soil organic matter and nitrogen, and decrease carbon to nitrogen ratio. Soil Sci. Soc. Am. J. 52:1668-1672.
18. Statistix, 1996. Statistix for windows. Analytical Software. P. O. Box 12185.
19. Tyson, S.C., and M.L. Cabrera. 1993. Nitrogen mineralization in soils amended with composted and uncomposted poultry litter. Commun. soil. Sci. Plant Anal. 24:2361-2374.
20. Weatherburn, M. W., 1967. Phenol-hypochlorite reaction for determine of ammonia. 39(8):971-974.
21. Rural Culture, and Agriculture. 1988. Soil Fertilizer. p:153-172.
22. Rural Development Administration. 1988. Soil Analysis Method.
23. Oh Sung Hoon. 1982. On the Biomass-C of Soil Microorganisms in Cultivated Soil Derived from Volcanic Ash Jeju-Do. MS. D. Thesis. Cheju National University, Chejudo, Korea.
24. Hang-Yeon Weon, Jang-Sik Kwon, Jang-Sun Suh, and Woo-Young Chȯi. 1999. Soil Microbial Flora and Chemical Properties as Influenced by the Application of Pig Manure Compost. Journal of Korean society of soil science and fertilizer. 32(1):76-83.
25. Lee, C.K., and K.S. Lee. 1975. Soil problems for developing grassland in Jeju. Journal of Korean society of soil science and fertilizer. 8(3):153-160.
26. Soil Microorganism Research Association. 1982. Soil Microorganism Method.