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Effects of Mixed Application of Chemical Fertilizer and Liquid Swine Manure on Agronomic Characteristics, Yield and Feed Value of Sorghum × Sudangrass Hybrid for Silage in Paddy Field Cultivation

Joo Hwan Hwang and Sang Moo Lee*
Department of Animal Science, Kyungpook National University, Sangju 742-711, Korea

ABSTRACT

This study was conducted to investigate the influence of the mixed application of chemical fertilizer (CF) and liquid swine manure (LSM) on the agronomic characteristics, dry matter yield, amino acids, minerals, and free sugars in cultivating Sorghum x Sudangrass hybrid (SSH) on paddy soil. The field experiment was designed in a randomized block design with three replications and consisted of CF 100% (C), CF 70% + LSM 30% (T1), CF 50% + LSM 50% (T2), CF 30% + LSM 70% (T3), and LSM 100% treatment (T4). The application of LSM was based solely on the nitrogen. Plant length, leaf length, leaf width and number of leaf were significantly higher in T4 ($p<0.05$), but stem diameter did not show significant differences among treatments. Stem hardness increased significantly ($p<0.05$) as the LSM application rate decreased, but sugar degree decreased significantly ($p<0.05$) as the LSM application rate decreased. Fresh yield, dry matter yield and TDN yield were the highest in T4, whereas the lowest in T2 ($p<0.05$). Crude protein, crude fat and crude ash were the highest in C, T4 and T2, respectively ($p<0.05$). However, NDF and ADF did not show significant difference among treatments. Crude fiber decreased significantly ($p<0.05$) as the LSM application rate increased. The total mineral content was decreased significantly ($p<0.05$) as the LSM application rate increased. Total amino acid content was higher in the order of T1> C> T3> T4> T2 ($p<0.05$). Free sugar content increased significantly ($p<0.05$) as the LSM application rate increased. The analysis of all the above results suggests that the application of liquid swine manure is very effective, considering the yield performance and the content of sugar degree and free sugar. In addition, liquid swine manure may be possible to grow Sorghum × Sudangrass hybrid without chemical fertilizer.
(**Key words :** Sorghum × Sudangrass hybrid, Manure, Yield, Mineral, Amino acid and free sugar)

Ⅰ. INTRODUCTION

Many researches are being carried out in various ways in many countries around the world including Korea to use animal manure as resources and fertilizers. More researches are called upon as the use of animal manure is emphasized as an alternative that can lead to sustainable and organic livestock production through reduced chemical fertilizer and cyclic farming (Lim et al., 2006). In recent years especially, consumers are more interested in eco-friendly and organic livestock products, and government also is focusing the direction of future livestock development on the high quality eco-friendly livestock products (Lee and Jeon, 2004). Therefore, the production of organic forage crops will play the greatest role in the production of future eco-friendly and organic livestock products, thus the use of cattle feces and urine is expected to increase. For these reasons, lot of studies are being carried out domestically on the cultivation of forage crops using animal manure (Lee et al., 1995; Ryoo and Jacob, 1997; Shin et al., 1998a; Seo et al, 2000; Lim et al. 2003; Yook and Choi, 2005; Na et al, 2006), and on the effects of the animal manure on soil environment (Shin et al., 1998b; Lee and Jeon, 2004; Lim et al., 2007; Kim et al., 2008; Yang et al., 2008;). Their studies, however, mostly on the growth of forage crops and on the soil by the application of animal manure, and most researches were conducted on upland soil. However, this research was carried out to investigate the influence of the mixed application of chemical fertilizer and liquid swine manure on the productivity, amino acids, minerals, and free sugars in Sorghum × Sudangrass hybrid for silage on paddy soil, and to provide the results as basic data for mixing

* Corresponding author : Sang Moo Lee, Department of Animal Science, Kyungpook National University, Sangju 742-711. Korea. Tel: +82-54-530-1224. E-mail: smlee0103@knu.ac.kr

liquid swine manure and chemical fertilizer to cultivate of forage crops on paddy soils in the future.

Ⅱ. MATERIALS AND METHODS

This field experiment was performed at a paddy field in the northwestern inland of Gyeongbuk, Korea. Especially, the experiment paddy field was on low-lying land. In order to solve this problem, drainage made 50 cm depth along the circumference of the field experiment to prevent flooding in rainy season. The field experiment was designed in a randomized complete block design of 3 repetitions with chemical fertilizer 100% treatment (C), chemical fertilizer 70% + liquid swine manure 30% treatment (T1), chemical fertilizer 50% + liquid swine manure 50% treatment (T2), chemical fertilizer 30% + liquid swine manure 70% treatment (T3), and liquid swine manure 100% treatment (T4) (see Table 1).

Table 1. Experimental design

Treatments	Mixing ratio of fertilizer types	
	CF (%)	LSM (%)
C	100	0
T1	70	30
T2	50	50
T3	30	70
T4	0	100

The conditions of the field experiment were a paddy field with higher organic matter and nitrogen content and lower phosphate content than the general upland soil as shown in Table 2.

The cultivated variety used in this experiment was P877F. Sowing was May 30 and harvest time was August 20 in 2009. Nitrogen, phosphorus and potassium components of using liquid swine manure were 0.45, 0.25 and 0.39%, respectively (Table 3).

Table 3. Chemical characteristics of used liquid swine manure

pH	T-N (%)	Av.P_2O_5 (%)	K_2O (%)
7.8	0.45	0.25	0.39

The application rates of chemical fertilizer were calculated in total nitrogen (200 kg/ha), phosphorus (150 kg/ha) and potassium contents (200 kg/ha) (see Table T4). The method of chemical fertilizer application was applied nitrogen and potassium with 60% as basis of fertilizer, and 40% as added fertilizer; and entire phosphorus as the basis fertilizer. Application rates of liquid swine manure were calculated in total nitrogen contents.

The LSM was also applied as much as 60% as the basis of fertilizer, and 40% as add fertilizer. Adding fertilizer was applied 35 days after seeding. The planting distance was 50 cm × 5 cm and each plot was 15 m^2 (3 × 5 m). For the investigation items and methods, the growth characteristics were observed 10 sampling 10 which is the most averaged plants for each repetition after cutting the central 2 rows of 6 rows. Sugar degree was measured by a PR-101 saccharimeter for extracted the juice at 20 cm from cutting point. Stem hardness was measured by KM spring gradiometer from the part 10 cm away from the cutting. Fresh yield was calculated after cutting of the two central rows. All dry matter rates were calculated by oven drying the samples at 65℃ for more than 4 days. Dried samples were ground and stored under vacuum to use as analysis.

TDN yields were calculated using the formula by Holland et al. (1990).

TDN dry matter yield = [88.9 − (0.779 × ADF)] × Dry matter yield per ha.

Nutritive values were analyzed using the AOAC method (1995), ADF and NDF were analyzed by Goering and Van Soest method (1970). The mineral composition was analyzed from the pre-treated samples using ICP (Inductively Coupled Plasma, Iris Intrepid, Thermo Elemental Co., UK). The

Table 2. Chemical properties of the soil before experiment

pH	OM	T-N	Av. P_2O_5	Ex. cation ($cmol^+ kg^-$)				CEC
(1:5)	(%)	(%)	(mg/kg)	K	Na	Ca	Mg	($cmol^+ kg^-$)
6.41	2.39	0.15	81.58	0.56	0.13	3.67	0.95	11.5

Table 4. The application amount of CF and LSM

Treatments	Application levels of N, P, K					
	CF (kg/ha)			LSM (kg/ha)		
	N	P	K	N	P	K
C (CF[1] 100%)	200	150	200	0	0	0
T1 (CF 70% + LSM [2] 30%)	140	105	140	60	33	52
T2 (CF 50% + LSM 50%)	100	75	100	100	56	87
T3 (CF 30% + LSM 70%)	60	45	60	140	78	121
T4 (LSM 100%)	0	0	0	200	111	173

CF[1]: Chemical fertilizer, LSM[2]: Liquid Swine Manure.

analysis of composition amino acid was done in the following sequence: 1 g of the pulverized sample was precisely taken and put in to a test tube; 10 mL of 6N-HCl was added, pressure reduced and sealed; hydrolysis at 110 ℃ in a dry oven for 24 hours; pre-treated and filtered by 0.45 μm membrane filter; and the filtered sample was analyzed by amino acid automatic analyzer (Biochrom 30, Biochrom Ltd, Cambridge, England). Free sugar was analyzed in the following order: exactly 5 g of sample was taken by Wilson method (1981); 100 mL of 80% ethanol solution was added; sugar composition was extracted repetitively for 2 hours at 80℃ from the heating mantle in the reflux cooling extraction unit; filtered by Whatman No. 5 and pre-treated; and was analyzed with HPLC analyzer (Waters 2414, Waters Co, USA) respectively. All data were analyzed using the general linear model (GLM) procedure of SAS (2002). Differences among treatment means were determined using the Duncan's multiple range test. A probability level of $p<0.05$ was considered to be statistically significant.

Ⅲ. RESULT ANA DISCUSSION

1. Growth characteristics and dry matter yield

The growth characteristics and dry matter yield are shown in Table 5. Plant length, leaf length, leaf width and number of leaf of SSH were the highest in T4 ($p<0.05$), but stem diameter was no significant differences among the treatments. Stem hardness shown higher in the order of C, T1 > T2 > T3 > T4 ($p<0.05$). Sugar degree (in stem portion) was significant improvement in the T4 with LSM compared to C with chemical fertilizer only ($p<005$), but there were no significant differences among the treatments

Table 5. Effects of LSM application ratio on agronomic characteristics and yield of SSH in the paddy field

Items	Treatments				
	C	T1	T2	T3	T4
Plant length (cm)	264.2^{b}	263.5^{b}	249.3^{b}	261.5^{b}	301.0^{a}
Leaf length (cm)	83.3^{b}	84.2^{b}	78.8^{c}	85.7^{ab}	89.0^{a}
Leaf width (cm)	4.4^{b}	4.6^{b}	3.8^{b}	4.5^{b}	6.7^{a}
Number of leaf (No.)	8.8^{ab}	8.3^{ab}	7.8^{b}	9.2^{a}	9.3^{a}
Stem diameter (Cm)	0.8^{ns}	0.8	0.7	0.8	0.9
Stem hardness (kg/cm^2)	2.8^{a}	2.8^{a}	2.1^{b}	2.0^{b}	1.9^{b}
Sugar degree (B^o)	6.2^{b}	7.7^{b}	6.7^{b}	7.7^{b}	9.9^{a}
Fresh yield (kg/ha)	$54,080^{c}$	$50,976^{d}$	$47,347^{d}$	$58,119^{b}$	$65,711^{a}$
Dry matter yield (kg/ha)	$12,920^{c}$	$12,115^{c}$	$10,786^{d}$	$15,518^{b}$	$18,373^{a}$
TDN yield (kg/ha)	$6,602^{c}$	$6,191^{c}$	$5,663^{d}$	$8,069^{b}$	$10,032^{a}$

ns : not significant.
[a, b, c, d] Means in a row with different superscripts are significantly different ($P<0.05$).

(C, T1, T2 and T3). Lee (2012b) reported that sugar degree was increased according to increasing of the LSM application. On the other hand, Seo et al. (2002) reported that sugar was decreased according to increasing of the LSM application.

Fresh yield, dry matter yield and TDN yield were shown higher in the order of T4> T3> C> T1> T2 treatments ($p<0.05$), especially higher in T4 and T3 treatments which was applied more LSM compared to C, T1 and T2. These results have the same trend as the studies by Lee (2012), Lim, et al. (2003), Choi and Yook (2000), and Lim, et al. (2006).

On the effect of application of LSM compared to CF, Jin et al. (1996) claimed that the animal manure application increased maize production by the chemical improvement of soil. Pain et al. (1986), Long and Gracey (1990) and Lee (2012b) reported that the application of low concentration LSM during drought periods at high temperature increased the production of forage crops because it reduced moisture stress owing to the supply of a large amount of water in addition to the fertilizer effect. Since we applied the LSM at time of drought, we can infer that LSM application at the time of SSH seeding and growing might enhance SSH growth and yield by reducing moisture stress.

2. Chemical compositions

The chemical compositions are shown in Table 6. Crude protein content showed the highest content of 5.7% in C treatment, while the lowest 4.9% in T2 treatments ($p<0.05$). This study showed similar to the result of Lim et al. (2003) and Na et al. (2006) in maize cultivation, and Park et al. (2006) in rye cultivation, all of whom reported reduced content of the crude protein with the application of LSM (N application is same as the chemical fertilizer) compared to the treatments with the CF only. The crude fat tended to significantly increase with the increase of the LSM compared to the CF ($p<0.05$). Crude ash showed significantly higher content in T2 compared to the other treatments. NDF and ADF contents did not show significant differences among treatments. Crude fiber shown higher in the order of C > T1 > T2 > T3 > T4 ($p<0.05$). Shin et al. (1999b) reported the increase in the contents of NDF and ADF according to the increase of LSM application, but Lim et al. (2003) claimed the slight decrease.

3. Mineral contents

The mineral contents are shown in Table 7. The mineral contents of all treatments were higher in the order of K > Ca > Mg. It is consistent with the report of Kim et al. (2012b). The mineral contents showed K > Ca > Mg > Mn > Fe in order, and the total content of the three minerals (K + Ca + Mg) accounted for 97% or more of the total mineral contents (Jeon et al. 2012; Lee and Lee, 2010; Lee, 2012ab; Lee and Kim, 2013). Ca content of C, T1, T2 and T3 showed similar, but tended a little decreasing in T4. Co and Cu contents appeared a very small trace mineral amount. Fe, Mn, Na and Zn were higher in T2 treatments. K content was higher in the order of T2 > T1 > C > T3 > T4, Mg was T1 > C > T2 > T3 > T4 respectively. Total mineral content showed the highest in T2 (10,496.3 mg/100g), while T4 treatment showed the lowest of 7,535.7 mg/100g. The total mineral content was higher in CF and

Table 6. Effects of LSM application ratio on chemical compositions of SSH in the paddy field (DM.%)

Items	Treatments				
	C	T1	T2	T3	T4
Crude protein	5.7^{a}	5.6^{a}	4.9^{b}	5.2^{b}	5.0^{b}
Crude fat	1.6^{c}	1.6^{c}	1.9^{b}	1.9^{b}	2.3^{a}
Crude ash	5.9^{bc}	6.1^{b}	6.5^{a}	5.7^{c}	4.4^{d}
NDF	70.7^{ns}	69.7	70.4	69.4	68.5
ADF	47.3^{ns}	47.9	46.1	46.7	44.4
Crude fiber	41.1^{a}	40.3^{a}	39.8^{ab}	38.5^{bc}	38.0^{c}

ns : not significant.
$^{a, b, c, d}$ Means in a row with different superscripts are significantly different ($p<0.05$).

Table 7. Effects of LSM application ratio on mineral contents of SSH in the paddy field cultivation (DM. mg/100g)

Items	Treatments				
	C	T1	T2	T3	T4
Ca	1,853.2	2,174.1	2,053.9	1,905.2	1,656.0
Co	0.1	0.2	0.2	0.1	0.1
Cu	3.5	4.2	3.9	3.3	3.3
Fe	43.8	38.6	58.5	25.3	25.3
K	6,986.4	7,090.0	7,540.3	5,327.4	5,143.7
Mg	753.8	910.8	735.9	727.7	622.6
Mn	53.1	54.8	62.3	53.7	53.6
Na	12.8	16.4	22.3	16.8	16.6
Zn	14.1	16.1	18.9	14.4	14.5
Total	9,720.8[a]	10,305.2[a]	10,496.3[a]	8,074.0[b]	7,535.7[b]
RI[1)] (%)	92.6	98.1	100.0	76.9	71.7

RI : relative index.
[a, b] Means in a row with different superscripts are significantly different ($p<0.05$).

mixed CF + LSM treatments (C, T1, T2) than the LSM treatment (T4), and tended to decrease significantly according to the increased application of the LSM ($p<0.05$). This result showed the same trend as Shin et al. (1998b, 1999a), who reported that the silage corn and rye of the CF treatment showed the highest contents of K, Ca, and Mg compare to the LSM treatment (as the basis of nitrogen 160~200 kg/ha).

4. Composition amino acid contents

The composition amino acid contents are shown in Table 8. Leucine showed the highest and histidine content was the lowest essential amino acids at all treatments. The content of the total essential amino acids was the highest in T1 treatment, but lowest in T2 treatment ($p<0.05$). Among non-essential amino acids, aspartic acid showed the highest content, and tyrosine content was the lowest in all treatments. Total non-essential amino acid was the highest in T1 treatment ($p<0.05$). The total amino acid content was in the range of 3,668.9~4,336.6 mg/100g according to mixed ratio of the chemical fertilizer and liquid swine manure. This experiment was the highest content of total amino acids in T1 treatment, which showed the highest content both in essential and non-essential amino acids ($p<0.05$). The reason of the highest content of the total amino acid in the T1 is thought to be attributable to the significantly higher content of crude protein in T1, as shown in Table 6. Kim et al. (2012b) reported that silage corn varies in the content of the amino acid of 3,653.0~5,433.1 mg/100g, and Do et al. (2012) reported that silage corn, P32W86 has 3,831.0 to 4,480.8 mg/100g according to the harvest time. Jeon et al. (2012) reported that SSH varies in content of the amino acid of 2,324.7~3,908.2 mg/100g.

Therefore, the amino acid content is considered to vary depending on the varieties, cultivation management and climatic conditions. Chiang et al. (1972) analyzed some species of concentrated feedstuff, and Kim et al. (2012a) studied on the amino acid content of some kinds of barley, both researchers reported that high amino acid contents were related to high crude protein contents.

5. Free sugar contents

The free sugar contents are shown in Table 9. Free sugar analysis revealed three sugars of fructose, glucose and sucrose in the SSH. The content of fructose, glucose and sucrose was higher in the treatments (T1, T2, T3 and T4) with the mixed application of chemical fertilizer and liquid swine manure compared to the C treatment of 100% chemical fertilizer ($p<0.05$). Especially, fructose, glucose and sucrose contents were very high in the T4 treatment

Table 8. Effects of LSM application ratio on composition amino acid contents of SSH in the paddy field (DM. mg/100g)

Items	Treatments				
	C	T1	T2	T3	T4
Threonine	166.4	191.3	157.4	168.6	165.6
Valine	274.6	295.4	261.6	280.8	248.3
Isoleucine	118.5	131.4	106.5	121.5	121.2
Leucine	324.2	319.4	271.4	292.5	329.3
Phenylalanine	228.0	257.5	228.5	250.5	229.5
Histidine	77.5	88.3	75.3	82.3	80.5
Lysine	258.7	282.6	231.7	255.8	241.6
Arginine	130.7	156.6	122.5	133.5	119.7
Sum of EAA	**1,578.6^{b}**	**1,722.5^{a}**	**1,454.9^{b}**	**1,585.5^{b}**	**1,535.7^{b}**
Serine	211.3	234.8	192.4	217.6	194.5
Glutamic acid	485.6	516.5	465.3	527.4	515.4
Proline	287.6	378.8	331.3	265.5	369.6
Glycine	198.6	225.4	185.6	206.4	193.8
Alanine	279.4	308.7	273.3	304.2	300.6
Tyrosine	79.5	68.7	54.4	85.6	62.7
Aspartic acid	819.7	881.2	711.7	657.4	573.4
Sum of NEAA	**2,361.7^{b}**	**2,614.1^{a}**	**2,214^{b}**	**2,264.1^{b}**	**2,210^{b}**
Total (EAA+NEAA)	**3,940.3^{b}**	**4,336.6^{a}**	**3,668.9^{b}**	**3,849.6^{b}**	**3,745.7^{b}**

EAA: Essential amino acids, NEAA: Non-essential amino acids.
[a, b] Means in a row with different superscripts are significantly different ($p<0.01$).

Table 9. Effects of swine slurry application ration on free sugar contents of silage corn hybrid in the paddy field (DM. mg/100g)

Items	Treatments				
	C	T1	T2	T3	T4
Fructose	3,888^{d}	4,492^{b}	4,403^{c}	4,444^{bc}	5,071^{a}
Glucose	4,345^{e}	5,129^{d}	5,276^{c}	5,436^{b}	5,574^{a}
Sucrose	3,378^{e}	4,570^{d}	4,775^{c}	5,586^{b}	5,930^{a}
Total	11,611^{d}	14,191^{c}	14,454^{c}	15,466^{b}	16,575^{a}

[a, b, c, d, e] Means in a row with different superscripts are significantly different ($p<0.05$).

($p<0.05$).

Free sugar content in the silage corn is very important because it affects the fermentation quality of silage ingredients (Lee and Lee, 2010, Lee, 2012a). In particular, the free sugar content acts as a good factor enhancing the taste in fermentation products (palatability) (Son et al., 2002). In addition, Jin et al. (1996) reported an increase of lactic acid in a fully fermented cattle manure (20 ton/ha) treatment compared with a standard chemical fertilizer treatment at corn cultivation times, and mentioned the feasibility of the silage quality improvement depending on the amount and method of cattle manure application.

Ⅳ. ACKNOWLEDGEMENT

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