【Article】

Effects of Cattle Barnyard Compost and Nitrogen Fertilizer Application on Yield and Chemical Composition of Maize (*Zea mays* L.) and Italian Ryegrass (*Lolium multiflorum* Lam.) in Double Cropping System

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Abstract

The objective of this study was to evaluate the effects of cattle barnyard compost (CBC) and nitrogen (N) fertilizer on soil and on yield and quality of maize (MZ) and italian ryegrass (IR) in double cropping system. The experiment used 4 rates of CBC and N fertilizer, respectively, i.e. CBC at rate of 0, 3, 6, 9 ton/10a and N fertilizer at rate of 0, 18, 36, 54 kg N/10a for MZ and 0, 10, 20, 30 kg N/10a for IR. Cattle barnyard compost increased organic matter and total N in soil. There was no significant difference in dry matter yield (DMY) of MZ among CBC treatments. Whereas the DMY increased as rise of N fertilizer applications from 0 to 18 kg/10a, thereafter, it was declined. Crude ash, crude protein and crude fiber (CF) concentrations of MZ increased with CBC application of 3 and 6 ton/10a and thereafter, the concentration declined. Total DMY and CF of IR increased as rise of CBC applications from 0 to 6 ton/10a, thereafter, declined. As for MZ, P and K concentrations were tended to increase as increased of CBC application. Rate applications of N fertilizer did not significantly effect on yield and chemical composition of IR, except for fraction of ether extract concentration.

Keywords: cattle barnyard compost, italian ryegrass, maize, nitrogen fertilizer

Introduction

Recently, nitrogen fertilizer excess in ecosystem has become a global issue in the world. It is well known that nitrogen fertilizers excess for long term can decline soil fertility and become an environmental problem such as eutrophication and high nitrate in plant and drinking water (Hesse and Misra, 1975; Singh and

Sekhon, 1979; Loomis and Connors, 1992). Application of nitrogen fertilizer could be halted either only to meet the requirement or with addition of organic fertilizer such as manure. Manures are natural fertilizers that have many beneficial effects in maintaining and improving soil condition, supplying mineral and reducing pollution (Hesse and Misra, 1975; Bernal *et al*., 1998). However, utilization of fresh manure directly should be avoided because both the growing seed and the decomposition of organic matter require nitrogen (Bernal *et al*., 1998). Seed growth will be reduced due to the competition for nitrogen. Composted cattle manure can reduce moisture contents, odor, and almost as effective in restoring productivity of soil as fresh manure. Composting is defined as a controlled microbial aerobic decomposition process to stabilize organic materials (Gilessman, 1991; Garcia *et. al*., 1992; Schlegel, 1992). Although, many physical, chemical and biological indices have been linked to the maturity of compost, it is unlikely that any single value will be valid for all type of compost. Dalzell *et al*. (1987) recommended that the final composts were achieved the maturity if carbon/nitrogen ratio are below than 20, no ammonia (smell) but musty smell, have a dark or earthy color and a light or fluffy texture.

The yield of forage increased with application of cattle manure (Taji *et al*., 1976; Kondo *et al*., 1979; Sugihara *et al*., 1979; Ito *et al*., 1982) as far as some extent of application amount. If cattle manure application combined with fertilizer, the dry matter yield of forage would not increase after 4 ton/10a of cattle manure application (Kondo *et al*., 1979). Cropping with heavy amount of manure up to 15 ton/10a decreased dry matter yield of maize (Taji *et al*., 1976). Chemical analysis of maize (Taji *et al*., 1976; Sugihara *et al*., 1979; Ito *et al*., 1982) and italian ryegrass (Taji *et al*., 1976) silage indicated that nitrogen, phosphorus and potassium content increased with increasing rates of cattle manure, while calcium and magnesium contents decreased due to antagonism with potassium. Taji *et al*. (1976) found that crude ash showed tendency to increase with increasing of manure application. Hesse and Misra (1975) reported that application of manure alone was not sufficient to meet the nitrogen requirement of maize, but it can be useful in addition of nitrogen fertilizer. Wilkinson (1979) suggested that nitrogen from fertilizer could be replaced by manure about 42%.

Although the effect of manure on the dry matter yield and silage chemical composition of maize and italian ryegrass had been investigated, utilization of compost combined with nitrogen fertilizer was still few. Moreover, the previous experiments commonly only observed effect of manure on the soil and forage yield. Nevertheless, the relationship among manure, fertilizer, soil and forage quality are very close. Therefore it is important to determine the effect of manure compost and fertilizer on soil, dry matter yield and chemical composition of the forage. The objective of the present study was to evaluate the effects of combination of cattle barnyard compost (CBC) and nitrogen (N) fertilizer on soil and on yield and chemical composition of maize (Zea mays **L**.) and italian ryegrass (Lolium multiflorum Lam.) in double cropping system.

Materials and Methods

1. Description of field

Experiment was carried out at the field of Experimental Farm of Hiroshima University (lat. 34°42’ N and long. 132°42’ E) from year 1997 to 1998. Average temperature and precipitation ranged from 17 to 25℃ and 162 to 256 mm/month in summer cropping, respectively and 2 to 15℃ and 30 to 135 mm/month in winter cropping, respectively. The area lies at an elevation of 250 m above sea level and is characteristic by granite regosol. The pH value of soil up to 20 cm from ground was 6.0-6.8 and 5.1-6.1 with H_2O and KCl solution, respectively. Concentration of total carbon (C), total nitrogen (N) and available phosphorus (P) were 0.25-1.14%, 0.09-0.91% and 136-700 ppm, respectively (Experimental Farm of Hiroshima University, 1992).

2. Composting process of cattle barnyard manure and sampling

The starting compost material was cattle dung mixed with saw dust from Experimental Farm of Hiroshima University. Composting were done twice i.e. from December 27^{th}, 1996 to April 8^{th}, 1997 and from June 19^{th}, 1997 to September 4^{th}, 1997 with amount of 2 ton each. Turnings were done every week in the first month and every two weeks in the rest. Composts were sampled and temperatures at 1 m depth were monitored for every 2 weeks before turning process. Three compost samples were taken from different zone of pile. These samples were composited and about 500 g sub samples retained for chemical analyses.

3. Treatments of cropping experiments and sampling

The experimental treatment comprised of 12 combinations of 4 rate of CBC and 4 rate of N fertilizer, i.e. CBC at rate 0, 3, 6, 9 ton/10a and N fertilizer at rate 0, 18, 36, 54 kg/10a for maize and 0, 10, 20, 30 kg/10a for italian ryegrass were basal dressing. Prior to field preparation for maize, phosphorus fertilizer 10 kg P_2O_5/10a and potassium 13 kg K_2O /10a were applied. While, for italian ryegrass, P fertilizer as magnesium phosphate was applied with amount of 50 kg/10a and K as KCl with amount 16.7 kg/10a. The combinations of CBC (ton/10a) and N fertilizer (kg/10a) were 0-0, 0-18, 0-36, 0-54, 3-0, 3-18, 3-36, 3-54, 6-0, 6-18, 9-0, 9-18 and 0-0, 0-10, 0-20, 0-30, 3-0, 3-10, 3-20, 3-30, 6-0, 6-10, 9-0, 9-10 for maize and italian ryegrass, respectively (Table 1). Then, topdressing was done for both crops at stage of 6-8 leaves with 10 kg/10a of N fertilizer. Each treatment had 2 replications, resulting in a total of 24 plots. Cattle barnyard compost and N fertilizer treatments were applied prior to seeding. Maize was sown 2 seeds per hill with 80 cm inter-row distance and 20 cm hill distance within each row on May 16^{th}, 1997. Then, topdressing was done at stage of 6-8 leaves with 10 kg N/10a of urea fertilizer. Maize was harvested at mid yellow ripe stage on September 8^{th} – 18^{th}, 1997. Italian ryegrass was sown with seeding rate of 3 kg seeds/10a on October 15^{th}, 1997 in the same field of maize. The plants were harvested at early bloom stage on April 21^{st}, 1998. After maize and italian ryegrass harvest, 3 soil cores of 0-20 cm depth for each plot were collected on September 19^{th}, 1997 and April 22^{nd}, 1998. All soil in the same plot were dried in room temperature, mixed thoroughly and sieved through a 1 mm mesh screen and analyzed for chemical analyses. Maize samples were taken 5 plants from each plot to determine dry matter yield (DMY). Italian ryegrass samples were taken by quadrate (0.5 x 0.5 m^2). All samples were taken triplicate for each plot. The samples were dried in an air drought oven with temperature 70℃ for 48 to 72 hours, milled with hammer mill through 1 mm of screen and analyzed for chemical analyses.

4. Analysis of chemical composition

The composts were analyzed for total C and N by C-N Recorder (NC-90A , Shimadzu Corporation™), for organic nitrogen by Kjeldhal method (AOAC, 1984), pH by pH meter fitted with a glass electrode (HM-30S, DKK-TOA Corporation, Tokyo, Japan), and ammonia by micro conway analysis method.

The soil samples were analyzed for pH by the pH meter using H_2O and KCl solution, for organic matter (OM) by muffle furnace with temperature 600°C for 2 hours (AOAC, 1984), for P available by Bray-II method using the UV spectrophotometer.

Forages were analyzed for chemical composition of OM, crude ash, crude protein (CP), crude fiber (CF), and nitrogen free extract (NFE) by the method of AOAC (1984). Organic cellular content (OCC), organic cell wall (OCW), organic a fraction (Oa) and organic b fraction (Ob) in cell wall were determined by method of Abe and Nakui (1979). Organic matter of feed is divided into OCC and OCW fractions. Organic cellular content contains sugar, protein, lipids and others soluble substances. Organic cell wall is organic matter that undigested by amylase and actinase enzyme. It contains fiber materials in the form of cellulose and hemicelluloses, lignin and silica.

Organic b fraction is part of OCW those are undigested by cellulase enzyme. Nitrogen uptake utilization (NEU) was calculated as:

NUE = (biomass (DMY) N/applied N) * 100

Phosphorus (P) and potassium (K) of all samples were analyzed by UV spectrophotometer (UV/VIS Spectrophotometer V-520, Jasco Corporation, Japan™) and emission spectrophotometry method (AA-6600F, Simadzu Corporation, Japan™), respectively.

5. Statistical analysis

The values of soil properties and dry matter yield and chemical composition of forage were statistically analyzed by the multiple regression analysis by the following model:

$Y = a_1CBC + a_2CBC^2 + a_3N + a_4N^2 + a_5Crops + b$

Where:

Y : each value (soil properties, forage DMY and forage chemical composition).

CBC : amount of cattle barnyard compost application (ton/10a).

N : amount of nitrogen fertilizer application (kg/10a).

Crops : dummy variable of cropping seasons used for soil properties only, summer crop (maize) = 1 and winter crop (italian ryegrass) = 0

$a_1 – a_5$: coefficient.

b : intercept.

Regression equation was developed by selecting all independent variables and significance of independent variables was assessed. Significant differences of values among CBC and N treatments were analyzed by student t-test thereafter. All calculations were made using a commercially available computer programs (Excel Statistics™, ESUMI Co., Japan).

Results

1. Changes of composition in cattle barnyard manure during the composting process

Changes of cattle barnyard component from the beginning to the end of the composting process are presented in Table 2. Ammonia concentration decreased as time of composting, mainly from second to forth weeks i.e. 0.22 to 0.03% (86%) and 0.41 to 0.20% (51%) on composting process in summer (June - September, 1997) and winter (December – April, 1996), respectively. Carbon and nitrogen (C/N) ratio value decreased as time of composting due to the decomposition of organic matter that occurred under aerobic composting process. The final composts assumed achieving the maturity i.e. no ammonia smell but musty smell, had a dark or earthy color and a light or fluffy texture. Chemical composition of final composts were also showed the maturity i.e. ammonia was very low (0 – 0.02). Nitrogen, P and K concentration of the compos in summer were 1.76, 0.92 and 2.56% and in winter were 1.61, 0.79 and 2.69%, respectively.

2. Effects of CBC and N fertilizer application on field soil

Chemical compositions of the soil after maize and italian ryegrass harvesting were shown in Table 3. Cattle barnyard manure increased ($P<0.05$) OM of soil after maize and italian ryegrass harvesting, while N fertilizer applications had no significant effect. Total N in soil after both maize and Italian ryegrass harvesting tended to increase (P=0.07) as increase amount of CBC. Both CBC and N fertilizer had no significant effect on pH, total C and C/N ratio of soil after maize and italian ryegrass harvesting. Available P concentrations decreased (P<0.01) as increase amount of CBC, mainly in soil after maize harvesting. Available P in soil after maize harvesting was significantly higher than that after italian ryegrass harvesting ranging from 140 to 230 ppm and 127 to 138 ppm, respectively.

3. Effects of CBC and N application on dry matter yield and chemical composition of maize.

There was no significant difference in DMY of maize among CBC and N fertilizer treatments ranged from 688 to 1636 kg/10a as shown in Table 4. Whereas DMY of maize had a tendency to increase as increase of chemical N fertilizer applications from 0 to 18 kg/10a i.e. from 854-1198 kg/10a to 1261-1636 kg/10a, thereafter, declined. Crude protein (CP) concentration ranged from 5.2 to 8.4%. It was highest in 3 ton/10a CBC application. However, its value was not significantly different from 6 ton/10 CBC application. On the other hand, CF concentration was highest in 6 ton/10a CBC application and it was not significant different from 3 ton/10a CBC application. Crude ash concentrations increased (P<0.01) with CBC application up to 6 kg/10a and thereafter, the concentration declined. Phosphorus (P<0.01) and K (P<0.05) concentration increased as rise amount of CBC applications. Nitrogen fertilizer with amount up to 18 kg/10a increased crude protein concentration of maize and up to 36 kg/10a as for CF concentration. Nitrogen uptake efficiency was decreased as decrease of CBC.

4. Effects of CBC and N fertilizer application on dry matter yield and chemical composition of italian ryegrass

Nitrogen applications fertilizer had no significant affect on DMY of italian ryegrass as shown in Table 5. Dry matter yield of Italian ryegrass ranged from 149 to 622 kg/10a. Dry matter yield of italian ryegrass increased with 3 and 6 ton/10a CBC applications, thereafter, declined. The highest DMY i.e. 622 kg/10a was achieved with 3 ton/10a CBC application. Phosphorus and K concentration tended to increase (P=0.10) with increased in amount of CBC. Different with maize, both CBC and N fertilizer application had no significant effect on CP concentration and nitrogen uptake efficiency of italian ryegrass. Organic cell wall concentrations increased as rise of CBC application, while OCC decreased (P<0.05). There was no effect of CBC application on Oa and Ob concentrations.

Discussion

Composting is a microbial process, therefore, any factors beneficial to microbial activities will increase the decomposition rate and potentially improve the physical and biochemical value of compost. Mature compost could be more value for crop nutrition. Zucconi and de Bertoldi (1987) have reported that high level of ammonia point to unstabilized material. Mature compost can be indicated by ammonia content below than 0.04%. According to composting process, both of the final compost samples had received an acceptable degree of maturity by the end of composting process. Significant effects of turning on microorganisms within windrow pile had been reported by Insam *et al*. (1996). Although functional changes in the microbial community with the composting process are basic characteristics, the change is more rapid when the compost windrow is turned. The turning accelerated the decomposition process resulting in mature compost with relatively higher N, P and K. Nitrogen, P and K concentration in this experiment were relatively higher than that of average composition of mature compost in some Asian countries i.e. 1.0 – 1.5%, 0.4 – 0.5% and 1.2 – 1.3% for N, P and K, respectively (Hesse and Misra, 1975)

The immediately available N in soil is nitrate or ammonium and thus addition of N fertilizer will increase the availability of N, for a time. This is the main reason for the spectacular results of N fertilizer (Hesse and Misra, 1975; Russel, 1988). However, this easily available N may be only temporary; it can be leached, denitrified, or fixed (Russel, 1988). Cattle barnyard compost can increase the potentially available N, although the immediate effect may be negative, but CBC has longer lasting effect for soil N. Therefore, in this experiment, total N had tendency to increase linearly as increased rate of CBC (P=0.07). Available P in soil was used by forage for their growth (Russel, 1988; Zaccheo *et al*., 1997). In addition, some of microorganisms could use P in form of inorganic P to convert to their cell as organic compound (Russel, 1988). As a result, available P in soil would decrease after plantation. Cattle barnyard compost had a significant effect on organic matter of soil. This result agreed with others previous experiments (Taji *et al*., 1976; Kondo *et al*., 1979; Sugihara *et al*., 1979; Ito *et al*., 1982). The increase of OM might be due to the effect of high organic carbon concentration in the compost in the field, which was suffered from the low C/N ratio before treatment (0.8 - 2.2). Therefore, soil showed direct response to application of manure. It is likely that the pH value did not change because of buffering action of CBC (Hesse and Misra, 1975). Trindade *et al*. (2001) had supported this result with their experiment on sandy loams soil.

Dry matter yield of maize in this experiment were 688 to 1636 kg/10a (Table 4). Sugihara *et al*. (1979) reported slightly higher DMY of maize in their experiment range from 1.321 to 1.747 kg/10a. Although CBC application showed no direct effect on DMY of maize, it effected chemical composition. Increasing amount of CBC applications from 0 to 3 ton/10a could slightly increase of CP and CA of maize from 7.06 to 7.65 % and from 4.39 to 5.45%, respectively. Nevens and Reheul (2002) have also observed significantly higher nitrogen concentration on maize when compost had been applied. The same results were found by Taji *et al*. (1976) and Sugihara *et al*. (1979) that CP and CA concentration were affected by manure in the first year of their experiment. Nitrogen fertilization decreased fiber content (CF, OCW and Ob) of maize up to 18 kg N/10. According to Russel (1988), the higher supply of N, the greater demand for C compounds for protein synthesis and the smaller proportion of carbohydrate left available for cell wall material. Increasing supply of N can decrease cell wall materials due to the protein cell content formation from N and C. At high N concentration, demand of C for protein formation will increase, as result, proportion of C for cell wall decreased. On the other hand, organic cell content increased as shown of increasing of OCC concentration. Cattle barnyard compost contained mineral that can be absorbed by maize. Increasing in absorption of mineral increased the mineral content uptake as shown in increasing of P and K concentration (Tables 4 and 5). Nitrogen uptake efficiency depends on others factors affecting plant growth (varietal characteristics, and the availability of light, water and other nutrients) in relation to N availability (Janssen, 1988). Brower and Powell (1998) reported that greater doses of manure did not increase crop biomass, but increased N losses through leaching. Therefore, increasing levels of CBC decreased nitrogen uptake efficiency as shown in Table 4.

Dry matter yield of italian ryegrass were ranged from149 to 622 kg/10a. These results were lower than DMY that was reported by Ito *et al*. (1981) i.e. 920 to 2210 kg/10a. However, those results were from 2 harvesting times. Kunelius *et al*. (2004) reported lower DMY of italian ryegrass in their experiment i.e. 254 to 288 kg/10a. Dry matter yield of italian ryegrass was significantly affected by CBC (Table 5). Effects of manure usually appear during the longer period due to the longer lasting available of their nutrient (Hesse and Misra, 1975). Italian ryegrass might accept residual effect of CBC from the previous plantation. Nakanishi and Tamba (1980) have also reported the same trend where in the first year, DMY of italian ryegrass increased with rising of manure application. Fiber yield (CF and OCW) increased up to 6 ton/10a of CBC application. Kondo *et al.* (1979) have also reported slight increase in CF when manure application increased from 0 to 4-8 ton/10a, although beyond that it decreased again. Muir (2002) has observed that application of compost increased ($P<0.05$) neutral detergent fiber concentration of forage kenaf (*Hibiscus cannabinus* L.). Nitrogen fertilizer was easy to supply N for forage, but commonly in a short period (Hesse and Misra, 1975; Russel, 1988). The direct effect of N fertilizer for DMY had been shown on maize cropping, while, no effect was observed on italian ryegrass cropping (Tables 4 and 5). The italian ryegrass plantation was started in fall season i.e. October 1997. Due to low temperature, the growth of italian ryegrass was slow. Although N had readily supplied on that time, it was not used efficiently by italian ryegrass. Laidlaw *et al*. (2000) showed that when N fertilizer was applied under low temperature for perennial ryegrass, the response was poor and the probability for loss of N by leaching was increased. Therefore, nitrogen uptake efficiency was lower in italian ryegrass than maize (Tables 4 and 5).

Conclusion

Cattle barnyard compost application might be beneficial to use especially in case of soil condition low in C/N ratio. Although CBC on soil condition as generally had no effect on short period, in this experiment it increased yield and quality of maize and quality of italian ryegrass. Combination of CBC with N fertilizer had tendency of a good effect on forage yield and quality. However, it is need to examine in the long term experiment.

Acknowledgment

The authors wish to express their appreciation to the contributions of Prof Nakagoshi Nobukazu, Dr Kikuchi Akira and the Experimental Farm of Hiroshima University in terms of technical assistance, advice and general cooperation with the study.

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（2007.2.23 受理）

Table 5. Effects of cattle barnyard compost (CBC) and nitrogen (N) fertilizer on dry matter yield (DMY) and chemical compositio of italian ryegrass.

Treatment		DMY	Chemical composition (% on a dry matter basis)												
CBC (ton/10a)	N (kg/10a)	(kg/10a)	DM	CA	EE	CP	CF	NFE	P	K	OCC	OCW	Oa	Ob	NUR[c]
0	0	149	21.70	7.41	2.19	6.88	22.9	60.6	0.09	0.75	43.2	49.4	13.47	36.0	0.64
0	10	215	23.07	7.07	2.37	7.33	25.3	58.0	0.13	1.50	44.1	48.3	10.85	37.4	0.49
0	20	241	23.44	6.91	1.55	7.22	22.9	61.4	0.19	1.43	46.8	46.8	12.28	34.5	0.36
0	30	221	23.62	7.12	2.38	7.39	23.2	59.9	0.16	1.42	46.6	46.2	10.65	35.6	0.26
3	0	283	21.83	7.78	2.43	7.02	25.2	57.5	0.15	1.60	41.0	51.2	13.42	37.8	0.40
3	10	223	22.72	7.07	2.06	7.54	22.9	60.5	0.14	0.94	47.1	45.8	12.09	33.7	0.26
3	20	416	22.43	7.36	2.13	6.80	24.3	59.4	0.25	1.49	44.9	48.3	12.58	35.8	0.35
3	30	622	22.42	7.21	2.53	6.94	25.4	57.9	0.23	1.50	44.7	48.8	10.85	37.9	0.44
6	0	407	20.42	8.07	2.53	7.49	24.9	57.0	0.21	1.77	40.4	51.5	12.74	38.8	0.37
6	10	485	21.16	7.85	2.34	7.93	27.1	54.8	0.17	1.46	40.6	52.1	11.09	41.0	0.39
9	0	261	21.88	7.79	2.81	7.20	22.7	59.5	0.29	2.36	44.3	47.9	12.37	35.6	0.16
9	10	299	22.66	7.88	1.88	6.89	24.9	58.4	0.19	2.09	44.5	48.3	11.14	37.1	0.16
Coefficient of independent variables															
Constant		112.5	-	-	2.34	-	23.08	60.09	0.12	1.21	43.3	48.94	-	-	-
CBC		96.70***	ns	ns	ns	ns	0.69***	- 0.98***	0.02**	ns	- 0.94**	0.92**	ns	ns	ns
CBC^2		.-8.69***	ns	ns	ns	ns	- 0.07***	0.09*	ns	0.01*	ns	ns	ns	ns	ns
N		ns	ns	ns	- 0.06***	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N^2		ns	ns	ns	0.002***	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
R^{2a}		0.75	-	-	0.563	-	0.32	0.39	0.57	0.69	1.57	0.49	-	-	-

DM, dry matter; CA, crude ash; EE, ether extraxt; CP, crude protein; CF, crude fiber; NFE, nitrogen free extract; P, phosphorus; K, potassium; OCC, organic cellular content; OCW, organic cell wall; Oa, organic a fraction; Ob, organic b fraction;
ns, not significant; *, **, ***, significant at 10%, 5% and 1% levels, respectively.
[a] R square; [c] NUR, nitrogen uptake efficiency, calculated from N biomass/N applied * 100