Fertilization Efficiency of Livestock Faeces Composts as Compared to Chemical Fertilizers for Paddy Rice Cultivation

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Key words: Livestock faces, Compost, Fertilization efficiency, Rice

Abstract

Soil NH_4-N content became higher in proportion to the increase in the urea application rate, while in livestock faeces compost (LFC) plots, it became lower than in urea plots and had no significant difference statistically among LFC plots. There was a close relationship between phosphate fertilization rate and the increment of soil available phosphate content after experiment resulting $y=0.1788x-6.169$ $(R^2=0.9425)$ *when applied fused superphosphate fertilizer, and* $y=0.0662x-2.689(R^2=0.9315)$ *when applied LFCs by the same amounts of phosphate (x: phosphate application, kg* ha^{-1}*, y: increment in soil available phosphate content, mg* kg^{-1}*). Plant height, number of stems, nutrients uptake by rice and rice yield showed higher levels in N 100, 150% application plots of chemical fertilizers, while every LFC plots exhibited lower values and no significant difference among them. Relative nitrogen fertilization efficiencies of LFCs compared to urea was 12.3% for cattle faeces compost (CaFC), 8.8 for swine faeces compost (SwFC) and 24.6 for chicken faeces compost (ChFC), respectively.*

Introduction

In 2009, the Gyeonggi Province area surrounding Seoul produced livestock faeces amounting to about 8.3Tg which was 20% of the total production in Korea. Therefore, the environment-friendly management of livestock faeces is one of the greatest issues in order to preserve the rural environment in this area.

In Korea, there has been an application standard of LFCs for crop cultivation since 2000. This standard considers LFCs as a substitute for conventional manure. It recommends that the relative application rates of LFCs compared to that of conventional manure are CaFC 100%, SwFC 22% and ChFC 17%, respectively.

However, LFCs generally contain a high content of P, and therefore it could be a substitute for P fertilizers as described by Jakob et al. (2002). So in this paddy rice cultivation experiment, the fertilization efficiencies of N and K in LFCs as compared to chemical fertilizers were investigated to find out the proper application rate of them when LFCs are supposed to be applied as P fertilizer.

Materials and methods

Three application levels of LFCs were applied by the equivalent amounts of 50 (Com. N 50%), 100 (Com. N 100%) and 150% (Com. N 150%) of recommended N application rate by soil test, and also treated the same amounts of N, P, K with those

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[2] As above

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of applied by LFCs using urea, fused superphosphate and potassium chloride (Fer. N 50%, Fer. N 100%, Fer. N 150%). Three kinds of LFCs, CaFC, SwFC and ChFC, were made by mixing in the same proportion of sawdust and LFCs, and fermented thoroughly. The chemical properties of LFCs are shown in Tab. 1. Applied amounts of LFCs in N 100% treatment were 13.8 Mg ha^{-1} for CaFC, 10.3 Mg ha^{-1} for SwFC and 6.3 Mg ha^{-1} for ChFC and they were applied 7 days before transplanting date of rice seedlings.

Tab. 1: Chemical properties of livestock faeces compost used in the experiment

(Unit: fresh weight %)

Livestock composts	OM	T-N	P_2O_5	K_2O	CaO	MgO	Water
Cattle faeces compost	40.9	0.97	1.33	1.66	1.57	0.62	46.7
Swine faeces compost	38.6	1.26	3.99	2.76	4.36	1.52	41.3
Chicken faeces compost	45.8	2.11	2.96	2.49	6.03	1.19	31.7

Twenty-five day old rice seedlings (cv. *Chucheongbyeo,* Japonica type) were transplanted in a space of 0.3 by 0.14 m at 0.90 by 0.98 m confined plots with Seogcheon silty loam (coarse loamy, mixed, non-acid, mesic Fluventic Haplaquepts) on May 20 and harvested on Oct. 10, 2009. Selected chemical properties of the soil in the site are shown in Tab. 2. The recommended fertilization rates based on soil test were N 134, P_2O_5 75 and K_2O 47 kg ha^{-1}. All of the composts and fertilizers were applied as a basal fertilization. Plant height and tiller number were measured at main growth stages of rice such as tillering, active tillering, maximum tillering, panicle formation, heading and harvesting stage.

Tab. 2: Chemical properties of the soil used in the experiment

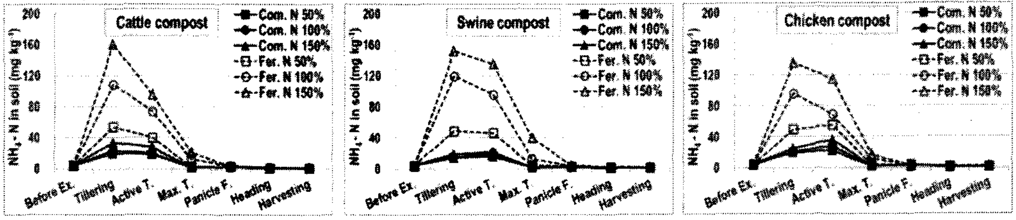
pH (1:5)	OM (mg g^{-1})	Av.P_2O_5 (mg kg^{-1})	Av.SiO_2 (mg kg^{-1})	Inorganic N (mg kg^{-1})	Ex. Cation (cmol kg^{-1})			CEC (cmol kg^{-1})
					K	Ca	Mg	
6.4	20.0	25	320	22.9	0.25	9.2	1.7	11.5

The surface soils collected at 15 cm depth from each plot were air dried, passed through a 2 mm sieve and used to determine soil properties by soil analysis method recommended by National Institute of Agricultural Science and Technology in Korea. Briefly, soil pH and EC were measured after mixing soil with H_2O at a ratio of 1:5. Soil organic matter and available phosphate were determined by Tyurin and Lancaster method, respectively. Exchangeable cations such as potassium, calcium and magnesium were analysed by extracting them with 1N ammonium acetate (pH 7) and determined by inductively coupled plasma spectrophotometer (ICP, GBC Integra XMP, Australia). Soil exchangeable ammonia level was obtained by Kjeldahl distillation from 2M KCl extracts. Soils were collected and analysed before experiment and at main growth stages of rice as mentioned above.

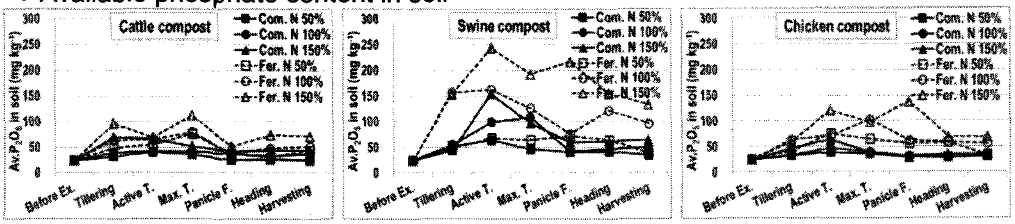
Results

Soil NH_4-N content became gradually higher in proportion to the increase in the fertilizer N (urea) application rate, while it was low in every LFC plot. P fertilizer raised the level of soil available P more than LFCs when the same amount of P was applied. LFCs application were less effective to increase soil exchangeable K than K fertilizer until the maximum tillering stage but this trend adversely changed after panicle formation stage or at harvesting stage showing more concentration of soil exchangeable K in LFC plots (Fig. 1).

o NH_4^+-N content in soil



o Available phosphate content in soil



o Exchangeable potassium content in soil

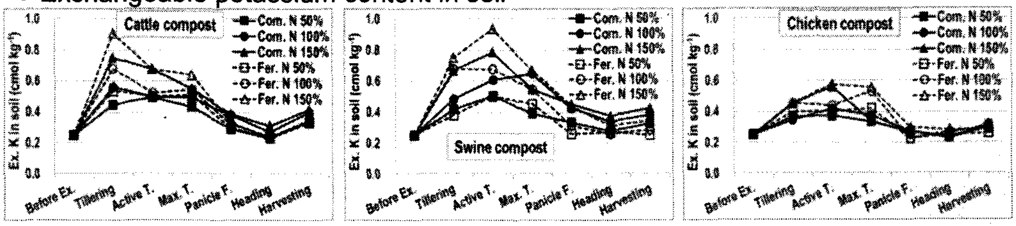


Figure 1: Changes of soil chemical properties at main rice growth stages by the application of livestock composts and chemical fertilizers

There were very close relationships between application rate of LFCs and soil organic matter increments after experiment and between phosphate fertilization rate and soil available phosphate increments after experiment. As for phosphate, the correlation was $y=0.1788x-6.169$ ($R^2=0.9425$) when applied fused superphosphate fertilizer, and $y=0.0662x-2.689$ ($R^2=0.9315$) when applied LFCs by the same amounts of phosphate with those in chemical fertilizer plots (x: phosphate application, $kg\,ha^{-1}$, y: increment in soil available phosphate content, $mg\,kg^{-1}$). But the relation between LFC application rates and the increments of soil exchangeable potassium content showed a low *coefficient of determination* (Fig. 2). Plant height, number of stems, nutrient absorption amount by rice plant and rice yield were high in 100, 150% N plots of chemical fertilizer, while every LC plot exhibited lower values and no significant difference among them (data not shown here).

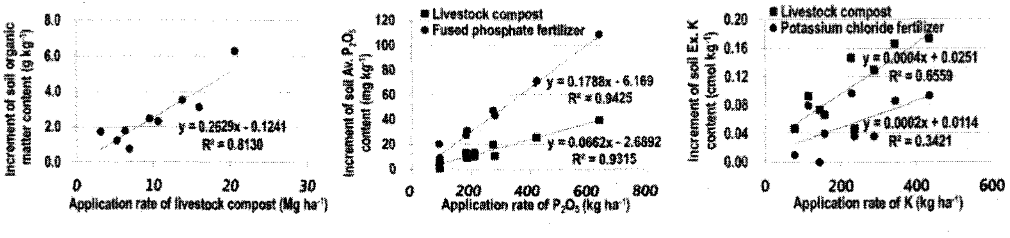


Figure 2: Correlation of fertilization rate and the increment of soil nutrients

Relative nitrogen specific fertilization efficiency of compost N as compared with urea N was 12.3% for cattle waste compost, 8.8% for pig waste compost and 24.6% for chicken waste compost, respectively (Tab. 3).

Tab. 3: Nitrogen fertilization efficiency of compost N and urea N

Treatment	Cattle waste compost			Swine waste compost			Chicken waste compost		
	Rice Yield (kg ha^{-1})	NFE †	NSE §	Rice Yield (kg ha^{-1})	NFE †	NSE §	Rice Yield (kg ha^{-1})	NFE †	NSE §
Compost N 50%	3,064	-	-	3,003	-	-	3,047	-	-
Compost N 100%	3,519	1.6	12.3	3,198	1.5	8.8	3,483	3.3	24.6
Fertilizer N 100%	5,021	12.8	100	5,289	17.1	100	4,963	14.3	100

† NFE; nitrogen fertilization efficiency

- NFE = (yield of treated plot – yield of untreated plot) ÷ N application rate

§ NSE; nitrogen specific fertilization efficiency of compost N as compared with fertilizer (urea) N

- NSE = (NFE of compost N 100% plot ÷ NFE of fertilizer N 100%) × 100

Discussion

The high correlation between P application rate and increment of soil available P after paddy rice cultivation would be a clue to find out the proper P fertilization rate of LFCs, inferring that a little more amount of LFCs P is required to meet the need of paddy rice than chemical P. The N specific fertilization efficiencies of LFCs N to urea N ranged from 8.8 to 24.6%, therefore only a small portion of N put by LFCs application could be a substitute for fertilizer N and the rest has to be supplemented with proper N sources. This appears to be similar to the result of Sørensen et al. (1994). Average of soil exchangeable K concentration during the main rice growth stage was not different statistically between LFC plots and chemical ones (data not shown here). This result implies that LFCs K has an equivalent effect to fertilizer K. This research needs supplementary experiments because of the different fertilization method of all basal fertilization in this experiment from the optimal one which includes the topdressing of N and K. Nevertheless, this result offers a useful piece of information on developing the practical fertilization method for organic cultivation of paddy rice.

Conclusions

Gyeonggi Province is the birthplace of organic agriculture in Korea mainly due to the various regulations to preserve the water quality of Han river which has been used as a drinking water resource for over 11 million peoples of Seoul-Gyeonggi metropolitans. Since this area has the biggest livestock industry in Korea, the faeces is the principal and renewable nutrient resources for organic farmers in this area. Many growers of organic paddy rice in Korea have used vegetable oil cakes as a nitrogen source, and there were some experimental results on the optimum rate of oil cakes for rice cultivation, therefore optimizing the appropriate rate of oil cakes and such results from this experiment as the relative N, P, K fertilization efficiencies of LFCs, etc. would be informative to achieve the proper fertilization for organic cultivation of paddy rice.

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