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Nitrogen use efficiency of late fall-applied urea and pig slurry for regrowth of perennial ryegrass sward

Sang-Hyun Park*, Tae-Hwan Kim, Bok-Rye Lee, SeJong Oh
Chonnam National University, Gwangju, Republic of Korea
*Corresponding author e-mail : grassl@jnu.ac.kr

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Introduction

Pig slurry is the most important organic resource in Korea, as estimated to be more than 15% of recycled animal manure. The use of pig slurry as an alternative organic fertilizer is the most viable recycling option as it is produced in large amount on pig farms that has usually less or not surface for cultivation of forage crops in Korea. Perennial grasses in grassland system regrow successively after harvests by cutting or grazing. The regrowth yield at each harvest would be a crucial determinant for the productivity of sward. During vegetative regrowth, soil mineral N and N reserves meet the N requirements for shoot regrowth. The aims of this study are to estimate the N use efficiency of urea and pig slurry applied at late fall in relation to the N availability for restoring organic reserves and constructing ultimate regrowth biomass during successive three cycle of regrowth of perennial ryegrass sward.

Materials and Methods

The study is based on field experiment conducted between November 2013 and September 2014. The experiment was carried out on a permanent grass sward, consisting mainly of perennial ryegrass (*Lolium perenne*) on a sandy loamy soil, which is located in the east-northern upland of South Korea (E127°14′, S35°12′). The experiment consisted of three N source treatments; 1) control plot which received no additional N, 2) chemical fertilizer-N as urea, and 3) pig slurry-N. For the treatment of pig slurry, pig slurry was applied at the rate of 200 kg N ha^{-1} with 198 L per plot, in which contains 75 kg P ha^{-1} and 105 kg K ha^{-1}. For the plot of chemical fertilizer-N, an equivalent amount of N was applied as urea and P and K fertilizers were supplemented to match with the amount applied by the pig slurry treatment (e.g. 1072 g urea, 823 g KH_2PO_4 and 58 g K_2SO_4 in a 25 m^2 plot). In control plot, no additional nutrients were supplied. Apparent N use efficiency (NUE) of urea-N or pig slurry-N for herbage yield and accumulation of organic compounds in remaining plant tissues at each regrowth period in urea- and pig slurry- supplied plot was compared as, the ratio between the values measured in unfertilized control removed from the values measured in urea-applied plot or in pig slurry-applied plot and the amount of N applied. Apparent N recovery of N applied (NR) with urea or pig slurry in the harvested herbage or in the soils was estimated by same calculation.

Results and Discussion

The analysis of the N concentration in terms of nitrate-N and ammonium-N of leachate, following N fertilization with urea or pig slurry at late-fall of the year preceding (18 Nov.), revealed that nitrate-N was the dominant fraction. However, ammonium contributed only marginally within a range of 0.3 - 1.2 mg L^{-1}. After one week of urea or pig slurry application (25 Nov.), nitrate concentration in the leachate collected from urea-, pig slurry- and non-fertilized plot was, respectively, 25.6, 16.4 and 9.1 mg L^{-1}. The first regrowth DM yield was 5.6, 4.8 and 4.1 t ha^{-1}, respectively, at urea-, pig slurry- and unfertilized control plot, and then gradually decreased with progressing cutting in all plots. The DM yield with urea-N was the highest up to the second regrowth, while with pig slurry-N for the third regrowth. Total herbage yield for three successive regrowth was 11.7, 12.0 and 8.8 t ha^{-1}, respectively, at urea-, pig slurry- and control plot. Apparent N use efficiency of urea for DM decreased from 10.0 kg DM per kg N at applied at the first cut to 6.3 kg DM N yield at the third cut, whereas that of pig slurry increased from 4.4 kg DM per kg N to 12.9 kg DM (Table 1).

***Table 1** Apparent N use efficiency (kg compound kg^{-1} N applied ha^{-1}) of urea or pig slurry for dry matter yield and the accumulation of soluble proteins, sugars and fructan in the remaining tissues (sum of stubble and roots) after cutting at 5 cm above ground level throughout three cycles of regrowth*

Sampling	Dry matter		Soluble proteins		Reducing sugars		Fructan	
Time	Urea	Pig slurry	Urea	Pig slurry	Urea	Pig slurry	Urea	Pig slurry
Wintering	-	-	0.143	0.112	0.252**	0.119	0.144	0.129
1st	10.03**	4.42	0.176*	0.128	0.406**	0.235	0.386	0.329
2nd	4.42	3.55	0.135	0.188*	0.382	0.397	0.218	0.314*
3rd	6.32	12.89***	0.118	0.313***	0.203	0.512***	0.170	0.408***
Total	28.90	31.30	-	-	-	-	-	-

*The significance of difference between urea and pig slurry was denoted by *, ** and *** for P < 0.05, P < 0.01 and P < 0.001*

These indicate that pig slurry is a slower release form compared to urea. Apparent N use efficiency of pig slurry for DM yield was largely higher at the third cut compared to that of urea. The physiological significance of organic reserves in regrowth has long well established in perennial forage species. Organic reserves in uncut remaining tissues are an essential role for initiating shoot regrowth. By direct quantification with ^{15}N tracing, it was estimated that about 60% to 80% of total N in regrowing shoots was derived from N reserves in remaining tissues for the early period of regrowth when the uptake of external was strongly depressed, whereas a large proportion from exogenous mineral N for the later period of regrowth (Ourry *et al*. 1994). Stubble (stem base and sheath) has a large proportion of organic compounds (i.e. 60% of total soluble proteins, about 65% of reducing sugars and about 80% of total fructan in remaining tissues after cutting). Organic compounds in stubble and roots showed a similar tendency with a gradual decrease with progressing regrowth cycle. Overall decreases in organic compounds from overwintering to the third cut were significantly less in pig slurry-applied plots compared to those in urea-applied plot. Total soluble proteins (sum of stubble and roots) at overwintering were 110.7, 106.1 and 89.52 kg ha^{-1}, respectively, at urea-, pig slurry- and unfertilized control plot. These values decrease by 58.1%, 28.7% and 67.7%, respectively, after the third regrowth. Similarly, total fructan at overwintering were 212.8, 200.6 and 181.2 kg ha^{-1}, and then decreased by 53.0%, 32.5% and 58.8% after the third regrowth, respectively, at urea-, pig slurry- and unfertilized control plot. Apparent NUE of two N sources for the accumulation of soluble proteins, sugars and fructan in the remaining tissues was distinctly different at each regrowth cycle (Table 1). Overall NUE of pig slurry-N for reconstitution of organic reserves was higher than that of urea-N, with higher N use efficiency at the later cycle of regrowth. It was found that the amount of inorganic N in the soils as affected by N fertilization with different N sources was closely related with pool size of soluble protein (P < 0.001, r=0.900), reducing sugar (P < 0.001, r=0.874) and fructan (P < 0.001, r=0.904) (Table 2). Significant relationships of pool size of each with herbage regrowth yield were also found organic reserves (P < 0.001, r= 0.842).

***Table 2** Correlations of N property in the soil or organic reserves in remaining tissues with herbage regrowth yield*

	Soil		Reserves in remaining organs			Regrowth
	Inorganic N	Total N	Proteins	Sugars	Fructan	DM yield
Soil inorganic N	-	r = 0.794***	r = 0.900***	r = 0.874***	r = 0.904***	r = 0.800***
Soil total N		-	r = 0.753***	r = 0.804***	r = 0.819***	r = 0.775***
Protein reserves			-	r = 0.951***	r = 0.936***	r = 0.814***
Sugar reserves				-	r = 0.935***	r = 0.826***
Fructan reserves					-	r = 0.822***
Regrowth DM yield						-

*The significance of difference between urea and pig slurry was denoted by *, ** and *** for P < 0.05, P < 0.01 and P < 0.001*

Conclusion

From the present study, it is thus concluded that pig slurry N applied at late-fall of preceding year is efficiently used for the successive regrowth in the following year without hazardous water pollution in winter when compared the effects of urea N.

References

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