Effect of Long-Term Heavy Application of Fresh Farmyard Manure on Yield and Nutrient Status of Forage Crops

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In Japan, farmyard manure (FYM) has commonly been used to increase crop yield and soil fertility of agricultural lands. Recently, however, draft cattle have almost all disappeared under changes in the agricultural situation, and a large amount of chemical fertilizers have come to be used instead of FYM.

On the other hand, increasing numbers of livestock and poultry resulted in a new problem how to dispose a great amount of excreta. Livestock farmers have to apply a large amount of animal excreta or fresh FYM onto agricultural lands one after another, because of a limited acreage of pasture and forage crop fields in this country.

In this connection, a field experiment has been conducted since 1968 to elucidate the effect of long-term heavy application of fresh FYM on yield and mineral quality of forage crops on the farm of Kyushu National Agricultural Experiment Station, Kumamoto.[6] Soil of the farm belongs to thick high-humic Andosols. The experimental treatment was composed of five rates of FYM application (0, 50, 100, 200, and 300 t/ha/year) with chemical fertilizer applied to each at the rate of 320 kg N, 160 kg P_2O_5 and 320 kg K_2O, and chemical fertilizer application alone at the rate of 480 kg N, 400 kg P_2O_5 and 480 kg K_2O/ha/year. Soiling maize (*Zea mays* L.) was grown for summer cropping followed by Italian ryegrass (*Lolium multiflorum* Lam.) for winter cropping, and this rotation was repeated every year. Before seeding Italian ryegrass every year, FYM was broadcast and mixed with the surface soil of about 35 cm depth. The chemical composition of FYM used is shown in Table 1. FYM was made of faeces and urine of cattle mixed with sawdust, and was piled up for one or two months before use.

Table 1. Chemical composition[a)] of farmyard manure applied (1973–82 mean)

	Moisture (%)	Total-C (%)	Total-N (%)	C/N Ratio	P_2O_5 (%)	K_2O (%)	CaO (%)	MgO (%)	Loss on ignition (%)
Mean	72.0	40.5	1.66	27.7	2.45	2.21	1.70	0.81	81.1
S. D.[b)]	4.53	2.62	0.57	10.4	1.12	0.94	0.95	0.24	6.17
C. V.[c)]	6.3	6.5	34.4	37.6	45.6	42.6	55.9	30.3	7.6

a): On oven-dry basis, except moisture content
b): Standard deviation
c): Coefficient of variation

Table 2. Changes in chemical properties of surface soil (0–15 cm in depth)

Farmyard manure (t/ha)	Period of application (years)	pH (H_2O)	Total-C (%)	Total-N (%)	Available P_2O_5[a)] (mg/100g dry soil)	CEC (meq)	Exchangeable cations (meq/100g dry soil)		
							Ca	Mg	K
0	5	5.9	9.0	0.65	0.9	36.3	10.7	1.07	0.37
	10	5.6	10.4	0.66	1.3	35.8	14.3	0.53	0.48
	15	5.4	10.2	0.62	4.3	37.9	10.4	0.21	0.26
50	5	6.0	8.6	0.64	1.4	35.8	13.4	1.91	0.24
	10	5.4	10.9	0.69	2.0	35.7	11.8	0.79	0.43
	15	5.5	10.9	0.65	4.8	39.8	9.5	0.49	0.25
100	5	6.1	8.7	0.66	1.6	37.2	14.5	2.21	0.30
	10	5.4	11.2	0.72	1.9	38.3	13.3	1.01	0.51
	15	5.6	11.4	0.67	6.7	41.1	10.9	0.75	0.47
200	5	6.0	9.4	0.70	2.2	39.6	14.6	2.52	0.56
	10	5.4	11.7	0.78	3.8	40.4	15.2	1.52	0.95
	15	5.8	11.3	0.72	16.2	45.3	14.9	1.75	0.90
300	5	5.9	11.0	0.76	2.6	42.8	15.4	3.08	1.09
	10	5.5	12.5	0.84	7.3	43.3	17.6	2.15	1.37
	15	5.8	12.8	0.79	28.2	48.3	19.4	2.80	1.10

a): extracted by Truog's reagent

Influences of long-term heavy application of FYM on nutrient status of the soil

1) Base imbalance due to excess accumulation of potassium

Table 2 reveals that contents of bases in the plowed layer (0–30 cm) increased remarkably with an increasing amount of FYM. A large accumulation of calcium and magnesium in the soil may contribute to the improvement of the poor productivity of the humus-rich volcanic ash soil. However, there occurred a simultaneous imbalance in the base status due to a large accumulation of potassium as compared with calcium and magnesium. Thus, the long-term application of FYM in excess of 100 t per ha per year resulted in a marked accumulation of exchangeable potassium amounting to about 1 meq per 100 g of dry soil. The large increase in potassium content may cause some troubles as mentioned later. Such a marked accumulation of bases, especially of potassium, caused by heavy application of FYM and slurry was also recognized in forage crop fields and pastures in Hokkaido, Tohoku,[8,11] Chugoku[10] and Kyushu[12] districts. It was also reported in England that the phosphorus and potassium concentrations in the surface soil (0–15 cm) of a pasture increased remarkably with the continuous application of a slurry (swine) for eight years.[9]

Fig. 1 shows the distribution of base contents in the soil profile. The contents of bases in the soil layer of 0–120 cm depth indicated that the FYM application caused a marked accumulation of potassium in the plowed layer, but, despite of it, the downward movement of potassium in the profile was fairly large, and that magnesium also moved down, but to a less extent than potassium. On the contrary, there appeared to be little movement of calcium to below 40 cm.

2) Accumulation of soil organic matter and increase in nitrification

Table 2 shows that a large increase in amount of total carbon and nitrogen occurred in the plowed layer by the long-term heavy application of FYM. Contents of inorganic

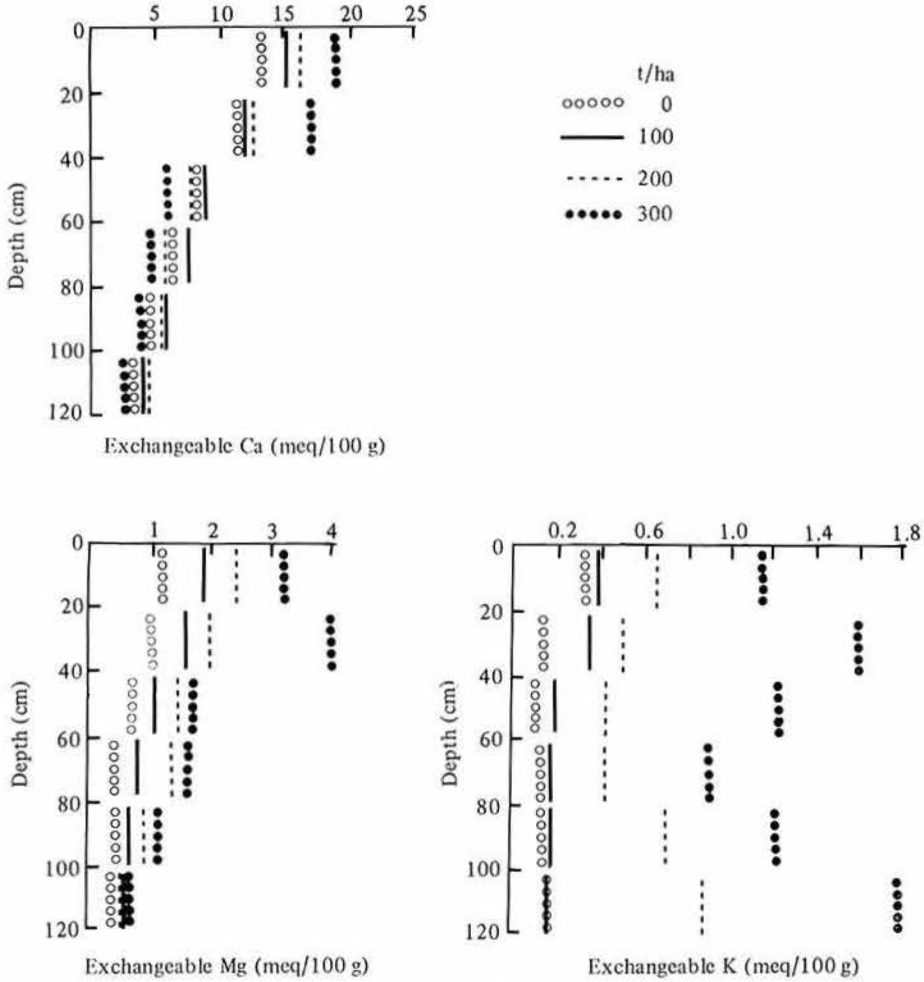

Fig. 1. Distribution of cations in the soil profile after harvesting the 10th crop (Italian ryegrass)

nitrogen due to nitrification also increased with increasing application rate of FYM. Concentration of nitrate-nitrogen (NO_3-N) in the surface soil under standing crops, therefore, increased remarkably by the heavy application of FYM as shown in Fig. 2.

Influences of long-term heavy application of FYM on yield and quality of forage crops

1) Decline in the rate of yield-increase

A large number of field experiments have been conducted for many years in Japan in order to determine the yield response of crops to the amount of applied FYM and compost.[4] However, the rate of application was limited to only 10 to 20 tons per ha and 30 tons at the most. At the farm of Kyushu National Agricultural Experiment Station, Kumamoto, a similar field experiment was carried out on a humus-rich volcanic ash soil for ten years since 1955, but the rate of application of farmyard manure ranged from 7.5 to 60 tons per ha in each year.[5] The results obtained by those experiments revealed that the yield-increase of crops was proportional to the amount of nutrients, especially nitrogen, in the manure.

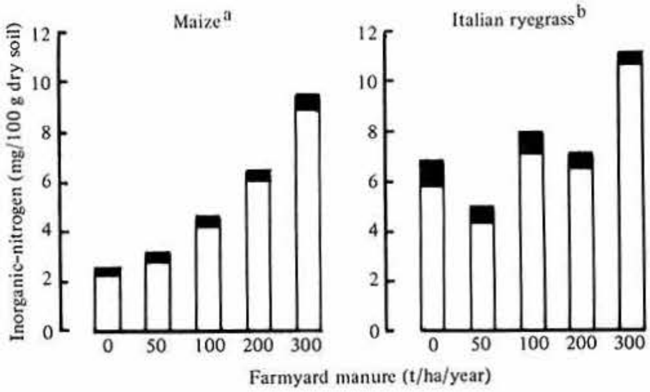

Fig. 2. Effect of farmyard manure application on the formation of inorganic-nitrogen in the surface soil (0–10 cm)

Notes: ■ : NH_4-N, □ : NO_3-N

a: sampled under the stand of the 9th crop (August 11, 1972)

b: sampled under the stand of the 8th crop (April 22, 1972)

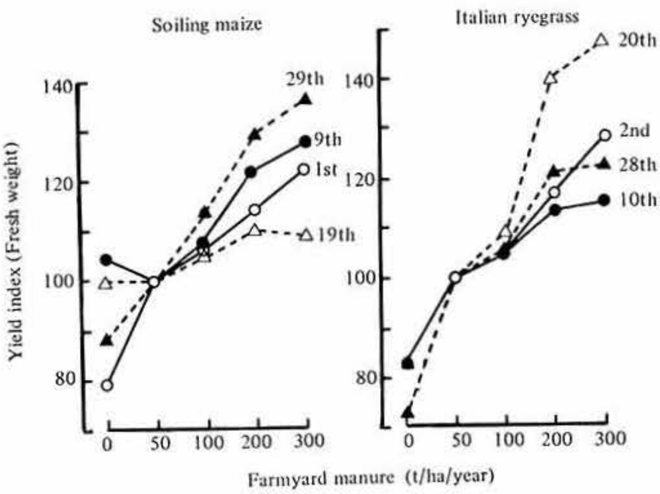

Fig. 3. Effect of application of farmyard manure on yield of forage crops at indicated cropping order

As for the present experiment, growth and yield of both crops, i.e. soiling maize (SM) and Italian ryegrass (IR), increased linearly with the increase in the amount of FYM applied in the first and second croppings. Afterwards, little differences were found in the plots which received FYM at the rate higher than 200 ton per ha, as shown in Fig. 3. The calciumchlorosis-like symptoms occurred on the later growth stage of IR after the fourth cropping in these plots. Symptoms of magnesium deficiency were also observed on SM of the 29th cropping in the plots with the application exceeding 200 ton per ha. Therefore, the appropriate amount of FYM application for forage crops should not be

Table 3. Influence of the farmyard manure supply on mineral composition[a] of forage crops (means of values 1971–82)

Farmyard manure (t/ha)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	NO_3-N (%)	K/(Ca+Mg)[b]
			— Soiling maize —				
0	1.36	0.18	1.16	0.32	0.19	0.08	1.0
50	1.36	0.19	1.05	0.30	0.22	0.08	0.9
100	1.42	0.20	1.35	0.26	0.21	0.11	1.2
200	1.50	0.20	1.78	0.24	0.17	0.17	1.8
300	1.54	0.21	1.93	0.22	0.16	0.18	2.0
			— Italian ryegrass[c] —				
0	2.82	0.30	3.07	0.73	0.21	0.20	1.5
50	3.08	0.35	3.13	0.66	0.24	0.30	1.6
100	3.33	0.39	3.64	0.63	0.25	0.40	1.9
200	3.55	0.44	4.37	0.57	0.23	0.53	2.4
300	3.77	0.48	4.61	0.52	0.23	0.58	2.7

a): (%), on dry matter basis
b): Equivalent ratio
c): Mean of values for three cuttings in each year

recommended only by considering crop yields.

2) Mineral imbalance in forage crops

Effect of FYM application on mineral contents in the forage crops is presented in Table 3. As shown by the means of data for 1971–1982, the heavy application of FYM increased the concentration of nitrogen, phosphorus and potassium in the both crops. On the other hand, the absorption of calcium and magnesium in the crops was retarded by the antagonistic effect due to the absorption of a large amount of potassium, and hence the K/(Ca+Mg) equivalent ratio in the forage crops came to be increased to a large extent. This fact suggests that in case of the heavy application of FYM, the ratios of K/(Ca+Mg) in forage crops might become higher than 2.0, which was reported as a critical level above which the risk of grass tetany increases.[3,7] Although the phosphorus content in the crops increases with the heavy application of FYM, the yield of dry matter might not increase owing to the low content of magnesium, which is necessary for dry matter production together with phosphorus.

3) Increase of nitrate nitrogen (NO_3–N) content of forage crops

Nitrification in the soil was promoted markedly by increasing the amount of FYM application. As a result, a large amount of nitrate nitrogen occurred in the soil and was taken up easily by crops. Table 3 reveals that nitrate content in IR increased significantly with increasing rate of FYM application, exceeding remarkably the critical value, i.e. 0.2% or 0.4% NO_3–N on dry matter basis, above which the nitrate poisoning might occur in ruminants such as cattle.[1,2]

Conclusion

The above results elucidated that the long-term application of FYM might increase soil fertility of Andosols. However, when a heavy application exceeding 100 ton per ha is made every year, the content of nitrate and potassium in forage crops will be increased markedly, as a result of increased nitrification and increased accumulation of potassium in the soil. Accordingly, the risk of grass tetany and nitrate poisoning may be increased in livestock. Thus, for the application of organic matter such as FYM, it must be emphasized that the nutrient input and output on agricultural lands should be balanced in the soil-crop-livestock system. Practically, it is recommendable that the amount of FYM applied should not exceed 100 ton per ha, above which nitrate accumulation, base-imbalance in soil, and yield decrease may occur. It is also reasonable to consider that content of exchangeable potassium in soil should not exceed about 0.6–0.7 meq per 100 g of dry soil.

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