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Effects of Long-Term Application of Rice Compost on Rice Yields and Macronutrients in Paddy Soil

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ABSTRACT : A long-term experiment was carried out to examine the effects of compost on the long-term trends and synergy effects with chemical fertilizer and saving the chemical fertilizers of paddy cropping. The experiment was conducted for the past 36 years with constant amounts of N, P, K and compost in a paddy field at Milyang, South Korea. Grain yield was significantly increased in the plots with compost application. Twenty five years after the compost treatment, grain yield was significantly increased and it reached almost 90% of NPK plots. The effect of rice straw compost on grain yield was not clear during the early cropping years about 60%, but it slightly increased there after about 95% during the late five years. In compost plots, soil organic matter content, K and SiO_2 was greater in the compost applied plots than with application of recommended doses of NPK. However, soil pH was reduced in compost applied plots and Ca, and Mg were remained unchanged when compared to the application of recommended doses NPK. Soil nutrient contents were less in compost applied plots than with the application of recommended doses of NPK along with compost but was found to be increased than that of un-fertilized plots. The present study indicated that the application of rice straw compost with NPK is the best of all and followed by NPK and Compost. However, treatment of Compost is time consuming and hard working desired and eventually non economical practice in mechanized agricultural systems, even though Compost is very useful source of improving the soil fertility and its physical characteristics and also the application of inorganic N and P are essential for sustaining high yield.

Keywords: rice compost, rice yield, macronutrients, paddy field

More than 10% of the total land area is being cultivated with paddy rice in Korea. Traditionally, in Korea, rice has been cultivated without or with only small amount of fertilizer, however, Korea has now changed to one of the highest fertilizer application rates to rice in Asia. Being located in the temperate zone, organic matter decomposes very slowly during the winter season and rapidly during summer. Both the removal and the burning off of rice straw lead to depletion of organic matter in the soil and may induce the lower soil fertility. Addition of manure with compost seems to be the primary important means for maintaining the soil fertility. Compost supplies nutrients and improves soil physical properties in crop production systems.

Application of plant waste materials may substitute chemical fertilizers by the notable increases in soil organic matter, mineralizable N, cation exchange capacity, available P and K (Kawaguchi *et al.*, 1983; Tanaka, 1978). Therefore a high rate of organic matter application is needed to improve soil productivity because organic matter percentage is about 2.5% in Korea which is very low compared to Japan (Kanareugsa *et al.*, 1983; Tanaka, 1978; Yoshida, 1981). Soil organic matter, due to its vital role in the maintenance of soil fertility, has been an object of constant study. Organic materials available as plant residues can be recycled either through composting or direct-incorporation into the soil.

High yielding rice fields are found to be associated with rising levels of soil fertility, owing mainly to the increase the nitrogen and organic matter content (Honya, 1975; Koyama, 1975; Onikura, 1975). Paddy soils are usually kept under flooded conditions for most of the rice growing season. The rate of organic matter decomposition is lower in paddy soils than in upland soils, so that the organic matter content in the former tends to be higher (Acharya, 1935; Asami, 1971; Yamane, 1961). There were many efforts improving soil productivity with cover crops in Korea and Japan (Cho *et al.*, 2001a,b; 2003)

In this paper, we evaluated the effects of long-term application of rice straw compost with and without recommended NPK.

MATERIALS AND METHODS

Field studies were initiated during 1967 summer and continued for the past 36 years at National Yeongnam Agricul-

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Table 1. Chronology of different rice varieties used for cultivation and treatments included in the a long-term fertilizer trial.

Fertilizer treatment	Experimental year	Cultivars used	Japonica type
	'67-'71	Palkyeng	Disease susceptible
1. Nil-fertilization	'72-'75	Milseong	Disease susceptible
2. Conventional	'76-'86	Nagdongbyeo	Disease resistant
3. Conventional + Compost	'87-'93	Palgongbyeo	Disease resistant
4. Compost	'94-'96	Hwanambyeo	Disease resistant
	'02-'97	Hwasambyeo	Disease resistant

Table 2. Chemical characteristics of rice straw compost.

pH	EC	OM	N	P_2O_5	K	Ca	Mg	SiO_2
	(dS/m)	(g/kg)	----------	----------	----------(%)----------	----------	----------	(mg/kg)
7.92	14.5	24.8	1.00	0.38	1.87	1.48	0.67	58

tural Research Institute (YARI), Milyang located in the Southern part of Korea (36°36'N, 128°45'E,12m). The soil is fine silty and classified as a Pyeongtaeg series (mixed, mesic, Typic Endoaquepts). A split plot design with three replications was used. Detail of treatments and the different varieties included for the past 35 years are shown in Table 1.

Urea, triple super phosphate and potassium chloride were applied to supply 120, 80 and 80 kg ha^{-1} of N, P and K respectively during 1967 to 1972 and 150, 100 and 100 kg respectively during 1973 to 2002. Rice straw compost, moderately decayed, was applied at the rate of 10,000 kg ha^{-1} from 1967 to 2002. Half of the N and the entire quantity of recommended P were applied as a basal application 2-3 days prior to the transplanting of seedlings and the remaining half of N was applied at tillering (30%) and panicle initiation (20%). Potassium was applied in split doses, 60% as basal application before transplantation and 40% during panicle initiation stage. Rice straw compost was placed on the surface and ploughed in 7-10 days before transplanting. The preparation of compost was performed by heaping rice straw after harvest and allowing 2-3 years for natural decomposition.

Every month the rice straw heap was turned upside down until the decomposition process completed. Chemical composition of the rice straw compost is shown in Table 2.

Cultivation methods and chemical analysis

The following cultivation practices were followed regularly for the past 36 years.

Thirty five days old rice seedlings were transplanted with five plants per hill at a spacing of 12 × 30 cm in each plot with a size of 6 x 8 m. Irrigation and pest control were done by conventional method. About 120-150 after transplanting, plants were harvested and the rice yield (unhulled rice with 14% moisture content) was measured, the soil fertility was evaluated by measuring pH (1:5, soil: H_2O), organic matter (OM; Tyurin method) content, cation exchange capacity (CEC), 1N NH_4OAc was used for extraction and measured in EDTA method before the coming of AA and ICP and then AA(Atomic Absorption Spectrometer, 2380 and 3300, Perkin elmer Optima) and ICP(Perkin elmer Optima 3300DV, USA) were used by age change for the soil cation and plant analysis.

RESULTS

All of the data in the figures are the mean of the 4-year and standard errors were not expressed for the improving the quality of figures and soil analysis was started after 7 years of the experiment start.

Grain yield

Throughout the 36 years of this experiment period, the chemical fertilizer and rice straw compost application contributed to the greater paddy yield than un-fertilized plants

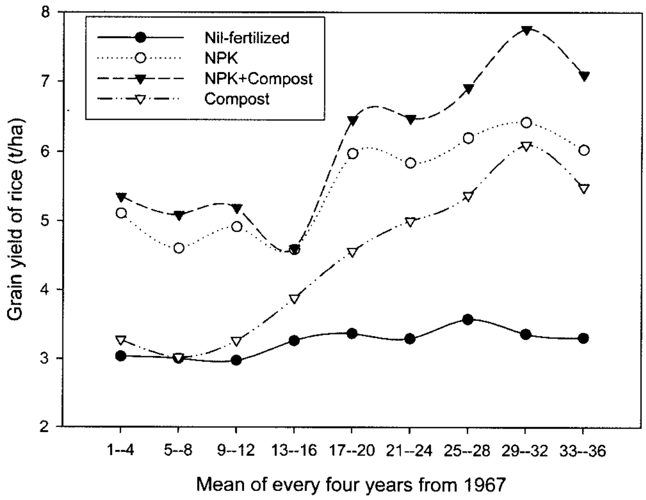

Fig. 1. Change of grain yield of rice as affected by fertilizer sources and cropping year in long-term experimental paddy field. Each value is the mean of 4 years result.

(Fig. 1). The best yield was obtained by the combination of chemical fertilizer with compost for all cropping durations. Rice straw compost without chemical fertilizer and no-fertilization maintained similar grain yield level with annual little fluctuations (data not shown) and it was similar with the compost application in the initial 8 years of cropping. A little improvement in yield was observed from the 1st year by the application of compost but the considerable increase was recorded from 9th year after cropping and maintained until 36 years of cropping.

Soil pH and organic matter

Soil pH mostly maintained with a little fluctuations between 5.1 and 6.1 and was mostly greater in NPK and NPK+Compost applied plots. And the probable reason for this fact may be due to continuous application of neutral fertilizer like urea for supply of N (Fig. 2). However, rice straw compost had lower pH than the application of inorganic fertilizer application.

No fertilized plots exhibited an initial increase in soil pH for 20 years, followed by a decrease.

Data presented in Fig. 3 indicate that the soil organic matter (OM) content generally increased with the increase in cropping years till 24 years with a rapid intermittent decrease during 17-20 years.

The OM content was maintained high in NPK+Compost and Compost plots. However, no-fertilization and inorganic fertilizers application showed low levels of OM content with (slightly high in NPK than no-fertilized plots). The OM content was started from 1.55-1.60% initially and it reached to 3.0-4.0% after 30 years of continuous cropping.

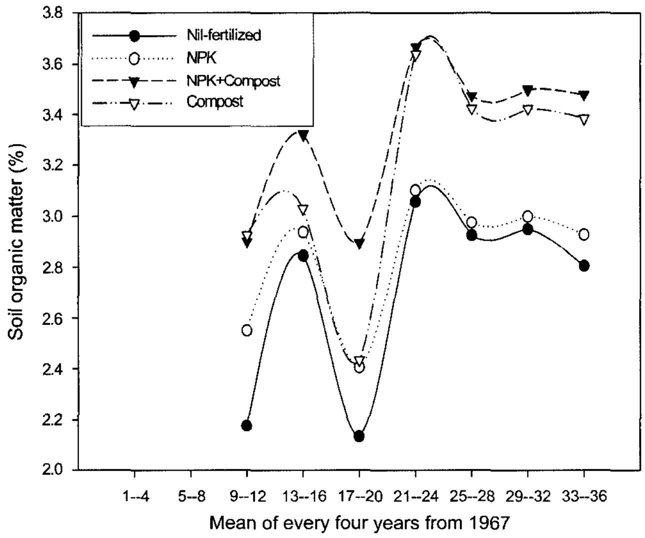

Fig. 2. Content of soil organic matter (%) as affected by fertilizer sources and cropping year in long-term experimental paddy field. Each value is the mean of 4 years result.

Soil P_2O_5, K, Ca, Mg and SiO_2

Soil phosphate content showed three different trends (Fig. 4). It was rapidly increased with NPK and little slowly in NPK+Compost applications. In compost treatment it was maintained steadily and found to be slowly decreased in no-fertilized applications. The P_2O_5 content in NPK+Compost ranged between 60 mg/kg at initial cropping years to 240 ppm after 36 years and it was four times greater than initial cropping year. Similar pattern was recorded in NPK and it was started from 60 (cmol + /kg) and reached at 185 (cmol + /kg) after 33-36 years and almost 3 times greater

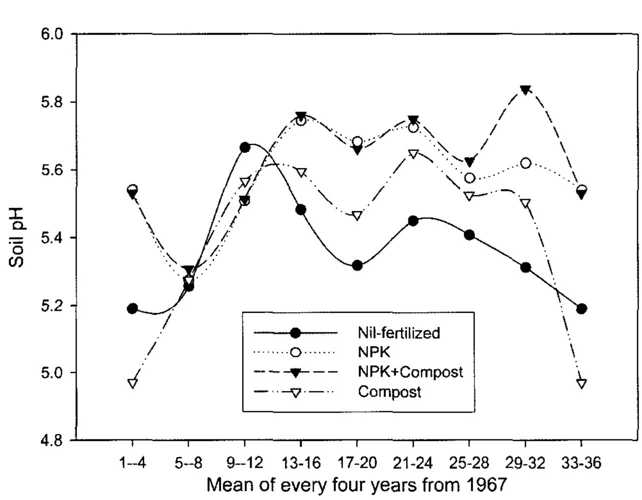

Fig. 3. Soil pH as affected by bertilizer sources and cropping year in a long-term paddy field. Each value is the mean of 4 years result.

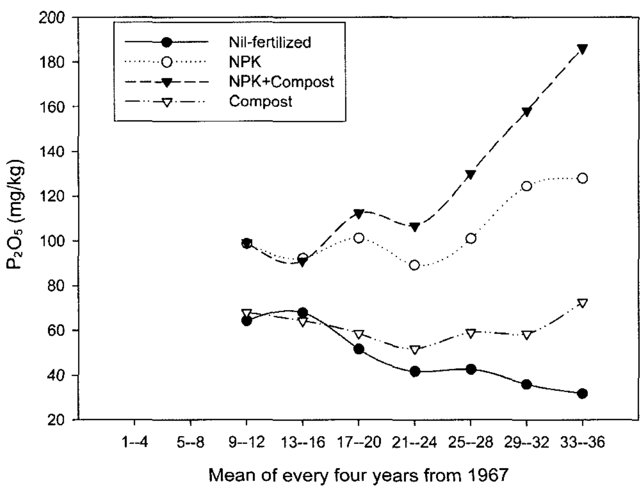

Fig. 4. Soil phosphate concent as affected by fertilizer source and cropping year in long-term experimental paddy field. Each value is the mean of 4 years result.

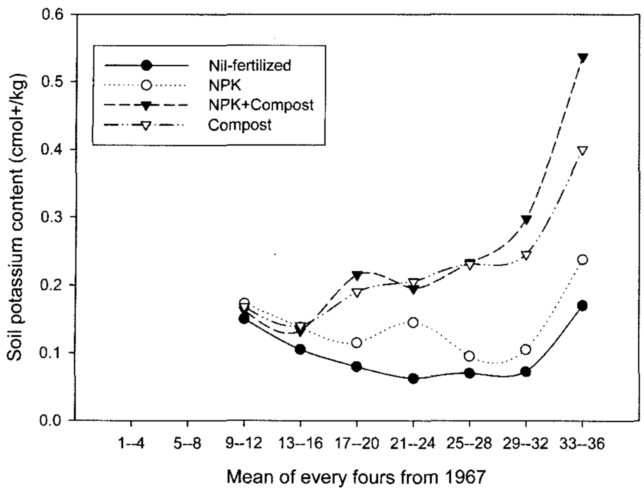

Fig. 5. Soil potassium content was as affected by fertilizer sources and cropping year in long-term experimental paddy field. Each value is the mean of 4 years result.

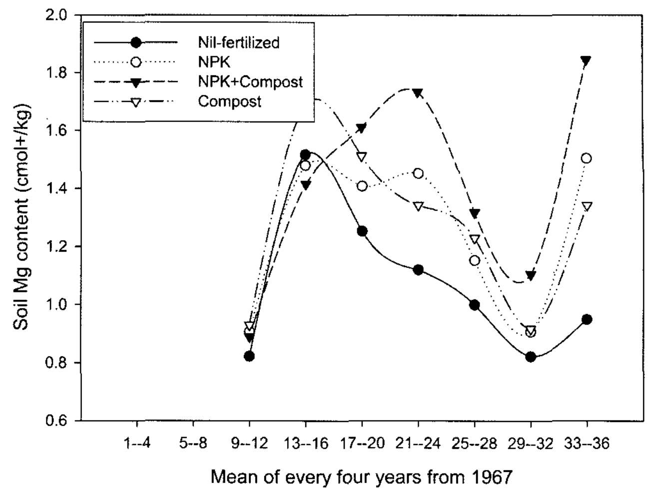

Fig. 7. Magnessium content of soil was affected by fertilizer sources and cropping year in a long-term experimental paddy field. Each value is the mean of 4 years result.

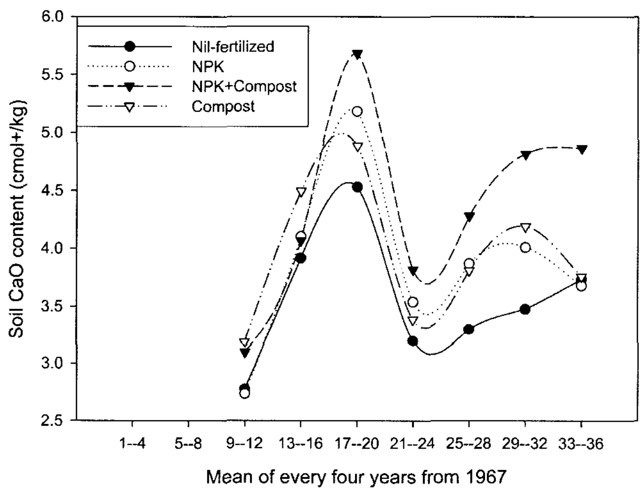

Fig. 6. Soil CaO content as affected by fertilizer sources and cropping year in long-term experimental paddy field. Each value is the mean of 4 years result.

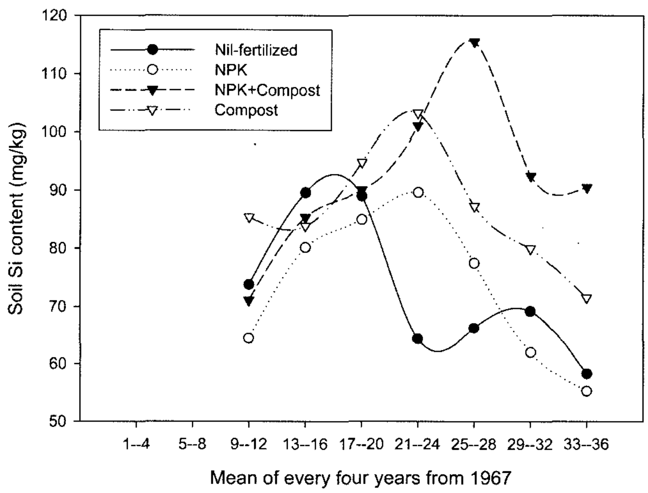

Fig. 8. Soil silicon content was as affected by fertilizer sources and cropping year in a long-term experimental paddy field. Each value is the mean of 4 years result.

than first year cropping. Compost application maintained or a little increase of OM content and it ranged between 50 and 80 (cmol+/kg).

Soil K content exhibited two different trends (Fig. 5). It was slightly increased by increasing of cropping year from 0.1 to 0.40 and 0.55 except rapid increasing in NPK+Compost and Compost. No-fertilized and NPK application exhibited steady maintenance between 0.05-0.20.

Soil calcium (Ca) content was ranged between 2.7 and 5.7 during the all cropping years (Fig. 6). The NPK+Compost ranked high in most of the cropping years. In NPK and Compost had second highest quantity of Ca, however no-fertilization had lowest level of Ca.

Soil Mg content was mostly ranged from 0.8 to 1.9 and same trend as that of Ca was recorded (Fig. 7).

Si content was positively correlated with the application of compost and compost and NPK+Compost had highest amount from 60 to 115 (mg/kg) and it mostly two times greater than no-fertilized or NPK alone applied plots (Fig. 8). In no-fertilized and NPK plots were mostly steady or a little increase until 13-20 and 13-25 years of rice cropping, respectively, and then slightly decreased. Compost didn't improve Si content in soil than NPK+Compost treatment. However, organic matter content increased upto 3.5 (%) at 32nd year compared to the 7th year with a little fluctuation among the cropping years.

DISCUSSION

Grain yield was closely related with the soil nutrients content and other soil physicochemical factors. In the present study, continuous application of rice straw compost with NPK chemical fertilizer contributed to the increasing of grain yield (Fig. 1) and this was basically due to the sustained nutrient supplying capacity of organic compost. Application of compost yielded same level like that of unfertilized plants for the first nine years and this may be mostly related with the incompletely decayed organic matter which may not supply the nutrients at initial cropping years. If high C/N ratio source were incorporated into the soil, the soil N can be immobilized by soil microorganisms for the degradation organic matter (Broadbent, 1970). The compost application, just a little effect was appeared in the 1st year but the considerable effect was started from nine years after cropping and maintained until 36 years cropping and the main reason was might be related with the greater soil nutrients from the rice straw compost as suggested earlier (Table 2; Songmuang *et al*., 1985). Delayed effect for grain yield was may be due to the lower N (1.0%) and lower organic matter content (2.48%) and the residue were greater in size which indicated the presence of uncomposed rice straw which mostly not easy for degradation (> 2 mm) and unable to supply the required nutrients immediately to the crops.

However, the plants received compost alone without any chemical fertilizer did not improved N fertility as indicated by Watanabe *et al*. (1978) because several useful N_2 supply was not found greatly by way of the biological N_2 fixation by estimating of natural supply and its main reason might be different climate and soil conditions.

Continuous application rice straw compost reduced the soil pH and obvious reason may be the release of organic acids during the degradation process. Exceptionally, continuous application of NPK resulted in high soil pH than the application of NPK with compost and it may be mostly related with the physiological nature of fertilizer urea. The unfertilized soil had reduced pH and this may be due removal of alkalic nutrients by the plants continuously from the soil (Figs. 1, 2, 3, 4, 5). The application rice straw compost increased the organic matter content steadily and it was reached to the maximum of 4% it this may be due to increase in the degradation by soil microbes or others (Cho, 2002). Initial increasing of soil OM in NPK plot than nil-fertilized plot was may be due to increase in residues of rice root and stubble by the improved plant growth. Soil organic matter level was similar between compost and NPK+Compost with a little high in NPK+Compost which may be originated from the improved plant growth. In South Korea, P in paddy soils is mostly recorded high and about 107 ppm than recommended level 100 ppm in 1989 and reported to be increasing year by year (Cho *et al*., 1998). However, most of Korean farmers do fertilizing annually before the soil tillage and leveling for the transplantation of rice seedlings or direct seeding. The main reason for this annual P supplying is the fast change to unavailable or low available type of P by combined with Fe, Al or Ca (Chang and Jackson, 1957; Thomas, 1977).

The present study indicates that the phosphorus should be applied to support grain yield to match the application of NPK. Other major nutrients, except P were high by the application of compost than NPK application alone and it indicates that P is the key element for the limited grain yield in the initial cropping years. Synergy effect for grain yield of rice was very significant in compost application either with or without NPK application.

In contrast to the P, soil K content was greater in rice straw compost treatment with NPK and it mostly related with the solubility of K which enabled the easy absorption of this mineral by the rice plant and chemically applied K was mostly used and residual K may remained. Additionally, increased grain yield also related with the uptake of K which mostly enhanced by the compost application (Park *et al*., 1990). The greater soil Ca content in NPK+Compost all the cropping years was mostly related with the solubility of Ca which is higher in high pH than low pH level. Additionally, the lowest level of Ca in un-fertilized plot also related with the low pH (Fig. 2). Even no fertilized with Ca, its solubility was mostly affected by the Compost or pH change of the soil. For the soil Mg, NPK+Compost treatment after 16 years cropping showed the synergetic effect because compost treatment was had similar Mg level as that of NPK application. It indicates that the Mg should be applied annually or several years interval for the sustaining rice yield. Flinn *et al*. (1982) introduced IRRI cultivars found severe yield damage by disease in the long-term experiment but in this experiment we did not used IR cultivars but mostly used Japonica cultivars which were recommended cultivars at the same cropping years. For the rice cultivar, yield damage from diseases was not found because of the introduced recommended cultivars from RDA (Rural Development of Administration), so dramatic yield increasing or decreasing was mainly originated from the soil nutrient conditions but it was not originated from the disease damage. Rice is called as a Si-philic plant and its contents range from 1 to 12% in the straw. However, paddy field in southern Korea is low Si content than recommended by R.D.A. (Rural Development of Agriculture) for harvesting of higher grain yield with high rice quality. The both treatments of Compost with and without NPK mostly contributed to the improvement of soil Si content. However the main reason of the lower Si content in un-fertilized soils than NPK applied soils may be related with the improved solubility of Si by improved plant growth. Considerable increase in different soil nutrients such as of N, P, K, Ca, Mg and SiO_2 by the application of compost with and without NPK reflection the earlier reports (Park,1990).

CONCLUSION

In the long-term experiment, compost was contributed the increase in organic matter and soil nutrients such as OM, K and SiO_2. The Soil pH was reduced by the organic acids. The contents of Ca and Mg were maintained similar level in the NPK plot. Additionally, compost application contributed to the improvement in grain yield when it was applied with NPK. In conclusion, rice straw compost is valuable for improving the soil fertility and physical characteristics enormously and chemical fertilizers without K should be applied for sustaining high grain yield while minimizing the soil and water pollution.

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