Evaluation of Composted Municipal Solid Waste for Agricultural Use in Vietnam

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***Abstract*—Recycling composted organic waste for agricultural use is gaining interest in Vietnam. This study investigated the effect of using composted municipal solid waste (MSW) as fertilizer to grow Sudan grass (*Panicum maximum*) and compared it with composted sewage sludge (SS), composted cow dung (CD), and traditional urea-based chemical fertilizer. A cultivation experiment (using containers) was conducted by growing the grass in sandy loam-textured soil using an automatic irrigation system in a greenhouse. ^{15}N labeled urea-N was used to distinguish N (nitrogen) that derived from urea-N or from compost. The various types of compost (MSW, SS, CD) and urea-N were applied as a basal fertilizer (incorporating into soil), while additional urea-N fertilizer was applied 4 weeks after planting. There was no significant difference in either grass shoot length or shoot dry weight among the MSW, SS, and urea-N treatments and their values were higher than grass grown under the CD treatment. The order of percent N uptake by grass derived from compost was as follows: MSW (39.4%) = SS (39.6%) > CD (17.1%). In contrast, approximately 4.0% of N derived from urea-N was assimilated by the grass. Approximately two-thirds of the urea-N fertilizer was lost by leaching while half of N derived from organic fertilizers remained in the soil. The amount of leached N from soil decreased in the following order: MSW = CD > SS. These results provide data needed to support the development programs for organic waste recycling and agricultural use of organic waste-based fertilizers in Vietnam.**

***Index Terms*—municipal solid waste, sewage sludge, N uptake, leaching, agricultural use, Vietnam**

I. Introduction

A large amount of municipal solid waste containing organic carbon and nutrients are produced daily. In Vietnam, most solid waste is sent to landfills, creating an environmental burden on the government to find suitable disposal sites.

The generation of solid waste increased annually by 10% in period of 2011-2015; that amount is expected to grow rapidly in future years. Municipal solid waste accounted for 46% of the waste generation with 63 thousand tons daily produced. Furthermore, the waste has high moisture content and contains a high proportion of organic matter, ranging from 54.0% to 77.1% across cities [1]-[4]. Therefore, biomass recycling has been gaining favor as an approach to reduce solid waste in landfills.

Monoculture agricultural practices in humid, tropical climates accelerate soil degradation. In Vietnam, degraded soil is widespread in agricultural areas. Most soil carbon (in topsoil) is lost via erosion; therefore, intensely-cultivated soils cannot retain nutrients [5]-[7].

Application of organic matter is recommended for improving soil productivity [8]-[10]. Most farmers believe that mineral fertilizers are more quickly assimilated by crops than organic fertilizers; therefore, farmers often apply organic fertilizers to crops at the time of planting (basal fertilizers) and then apply chemical fertilizers later when needed. However, the efficacy of this practice requires further study.

Manure is popularly used as an organic fertilizer worldwide. In addition, sewage sludge is becoming an important recyclable organic material in developing countries that are rapidly urbanizing [11], [12]. Recently, urban areas in Vietnam have begun to compost their solid waste. However, regulations on the recycling of organic fertilizers have not been sufficiently established in Vietnam [13]. Therefore, the development of composting techniques and utilization of compost has become an important focus of research.

Our study focuses on the efficacy of and mechanisms for using composted municipal solid waste (MSW) in soil-plant systems when applied in concert with chemical fertilization. We conducted a trial experiment to assess the usefulness of MSW for growing crops relative to using composted sewage sludge (SS) or composted cow dung (CD). Specifically, our study investigates the following aspects: (1) the effects of composted MSW on crop productivity and (2) the proportions of N (nitrogen) derived from composted MSW assimilated by plants, stored in soil, and leached to groundwater.

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II. Materials and Methods

A. Compost Sampling

We collected MSW from the Thuy Phuong waste treatment plant (Vietnam), and SS and CD from the Chugoku Yuki composting plant (Japan). The chemical properties of these materials are summarized in Table I.

TABLE I. Chemical Properties of the Materials

Constituents	Municipal solid waste (MSW)	Sewage sludge compost (SS)	Cow dung compost (CD)
T-C (g kg^{-1})	122.60	248.10	260.50
T-N (g kg^{-1})	9.90	37.70	24.70
NH_4^+ (g kg^{-1})	0.97	11.65	-
NO_3^- (g kg^{-1})	0.03	0.79	-
T-P (mg kg^{-1})	3.40	33.16	9.85
K (mg kg^{-1})	7.72	5.54	18.53
Mg (mg kg^{-1})	2.38	5.41	4.38
Ca (mg kg^{-1})	43.18	17.40	12.76
Zn (mg kg^{-1})	205.42	198.61	117.74
Cu (mg kg^{-1})	137.70	318.63	34.62
Cd (mg kg^{-1})	8.19	8.02	4.24
Ni (mg kg^{-1})	18.33	99.27	4.04

B. Cultivation Experiment

Our cultivation experiment was conducted using culture containers (0.45 × 1.05 m, depth: 0.32 m) filled with the decomposed granite soil (sandy loam). Sudan grass (*Panicum maximum*) was planted in the containers and grown with an automatic irrigation system in a greenhouse. A diagram of the experimental setup is shown in Fig. 1; a picture is provided in Fig. 2.

One of the four types of fertilizers (MSW, SS, CD, or urea-N) was applied to the upper 5 cm of the soil of each container at the beginning of the experiment (i.e., basal fertilization). The beginning N concentration of the experimental soils was 15.98 g N/m^2. Treatments were arranged in a randomized design with three replications.

Seeds of Sudan grass were sown into the containers at a density of 10 g/m^2, equivalent to approximately 210 seeds per culture container. Water was supplied continually to plants with an automatic watering apparatus at a necessary and sufficient amount.

Four weeks after sowing, the first additional (chemical) was applied at a rate of 18.38 g N/m2 fertilization along with 15N-labeled urea-N: 8% by atom. Six weeks later (10 weeks after sowing), the aboveground biomass of the mature grass was harvested by cutting it 2 cm above the soil surface. Four weeks after that, after the grass had regrown, it was fertilized again; then, the second harvest was conducted.

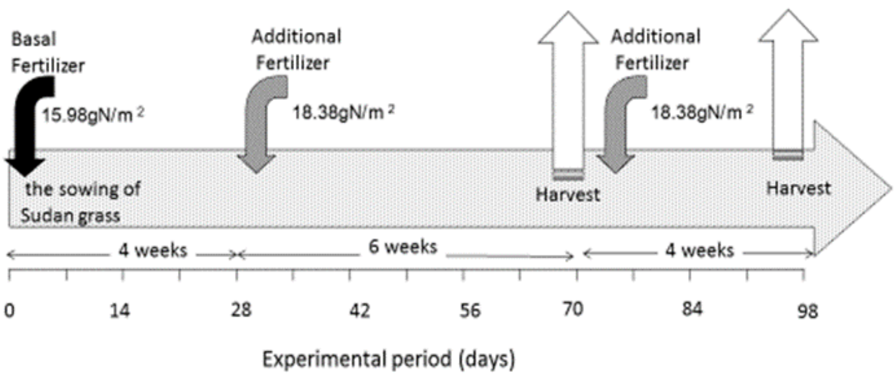

Figure 1. A diagram of the experimental setup

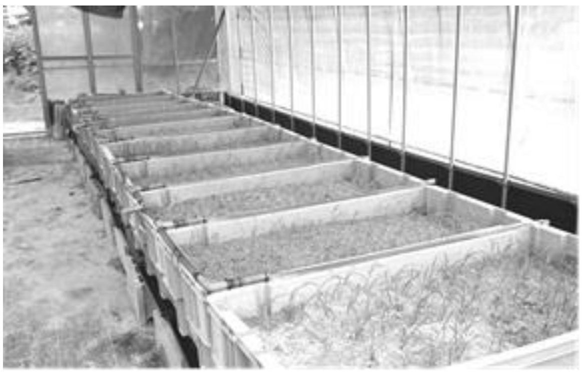

Figure 2. A picture of the experimental setup

C. Sampling and Analysis

Plant growth was monitored weekly by measuring the shoot length of five randomly chosen plants in each culture container. Length was defined as the height of top leaves. At harvest, grass was cut at 2 cm length above the soil surface to collect samples. At the end of the experiment, soil samples were collected from each container from the top 5 cm of the soil, from the 5- to 10-cm depth stratum, and from the bottom soil stratum. Plant and soil samples were dried in an oven at 105°C for 24 h, weighed, ground, and stored for further analyses.

Chemical analysis: Total N and C content were determined using a CN-Analyzer. 15N isotope ratios were measured in plants and soil samples (from stable isotope culture containers) using the CN-Analyzer coupled with isotope Quadrupole mass spectrometry [14].

Statistical analysis: Analysis of variance (ANOVA) was used to test whether effects of the experimental treatments on shoot dry weight and total N uptake were significant. When effects were significant at the 0.05 level of probability, the means for each factor pair were separately compared using the Fisher's least significant difference (LSD) test. Finally, ANOVA and LSD tests were applied to the factor scores to identify significant differences among treatments.

III. RESULTS AND DISCUSSION

A. *Effect of MSW on Crop Productivity*

To assess the effects of compost application on plant, we statistically compared shoot length and shoot dry weight of plants grown under each treatment type.

Shoot length: Changes in shoot length were evaluated weekly prior to the first harvest (Fig. 3). We found that before our first application of additional fertilizer (at week 4), shoot length after the MSW treatment was statistically shorter than that after the SS and urea-N treatments, but higher than that after the CD treatment. After the second fertilizer (urea-N) application at week 10, there were no significant differences in shoot lengths among the MSW, SS, and urea-N treatments; in addition, shoots grown under these treatments were significantly longer than shoots grown under the CD treatment. The slow-release of available-N following the application of MSW may result in a lower rate of plant growth in early growth stages. Therefore, application (as additional fertilizer) may have helped enhance plant growth in the MSW treatment. In later sections, we discuss N utilization relative to various forms of N.

Shoot dry weight: There were no significant differences among treatments in the dry weight (biomass) of shoots relative to the MSW, SS, and urea-N applications; in addition, biomass of shoots was significantly higher than the biomass of shoots obtained from the CD-treated containers (Fig. 4). These results agreed with the results we obtained from our shoot length experiment.

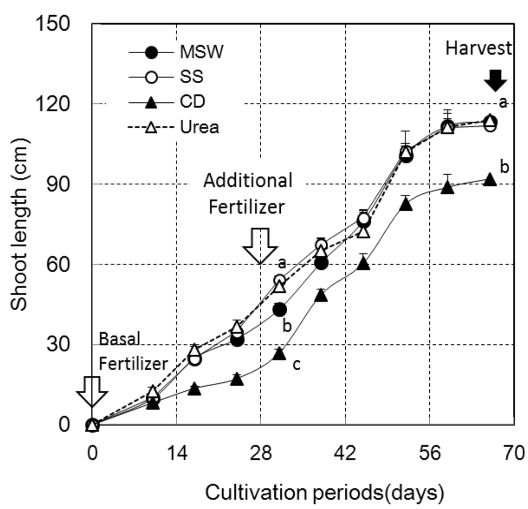

Figure 3. Changes in shoot length at the first harvest as influenced by different treatments.
Note: MSW, composted municipal solid waste; SS: composted sewage sludge; CD: composted cow dung.
Values are means ±SD (n=15). Means with the same letter are not significantly different from each other (p<0.05)

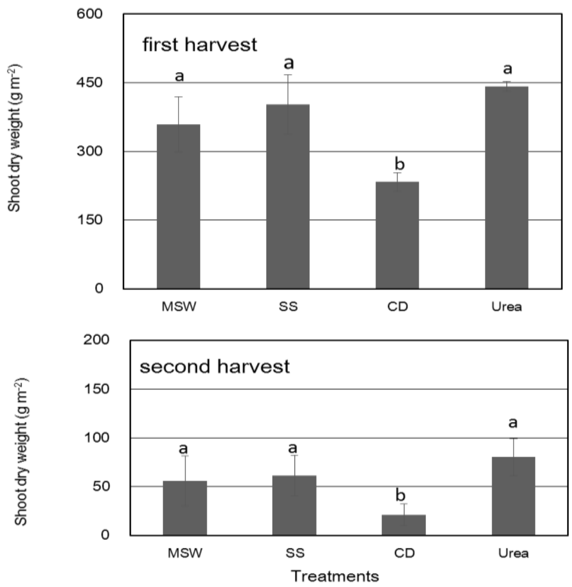

Figure 4. Shoot dry weight as influenced by different treatments.
Note: MSW, composted municipal solid waste; SS: composted sewage sludge; CD: composted cow dung. Values are means ±SD (n=3). Means with the same letter are not significantly different from each other (p<0.05).

In summary, when compost was applied as a basal fertilizer (and urea-N applied later as an additional fertilizer), the agronomical efficiency of the MSW compost was equivalent to the efficiency of the SS compost and chemical (urea-N) fertilizer treatments.

B. *Dynamics of Compost-N Amended Soil*

Efficient use of organic fertilizers on agriculture lands requires controlling both the quality of the raw material and the amount and dynamics of the nutrients applied. The fate of compost-N is relevant to plant productivity; however, excess N exported to water bodies has environmental consequences, such as eutrophication [8], [10], [15], [16].

Our measurement of ^{15}N isotope ratio in plants and soils of the stable isotope culture containers provided information about N dynamics of the applied N and enabled us to estimate the amount of N lost via leaching (Fig. 5).

N uptake by grass planted in the various types of composts we tested was higher than N uptake in the urea-N fertilized containers. The order of treatments relative to percent N uptake was as follows: MSW (39.4%) = SS (39.6%) > CD (17.1%). In contrast, only 3.6%−4.1% of urea-N was assimilated by the grass. N uptake by grass from compost-N in our study was remarkably higher than N uptake by plants fertilized with compost in other studies. In those studies, uptake generally did not exceed 15%–20% of the total N supply in the first year of growth [15]. In contrast, in our study, leaching loss of N was higher in the urea-N application treatment than in any of our other (compost) treatments. N loss in soil via leaching decreases with an increase in the N-immobilization rate. Although approximately two-thirds of urea-N was lost via leaching in our study, approximately half of N derived from organic fertilizers remained in the soil. N leaching, by treatment type, decreased in the following order: MSW = CD > SS. The less N is leached from the soil, the less likely the groundwater will be contaminated by NO_3^-. Despite higher leaching potential, urea-N applied as an additional fertilizer can provide an important role for an effect rate of MSW treatment.

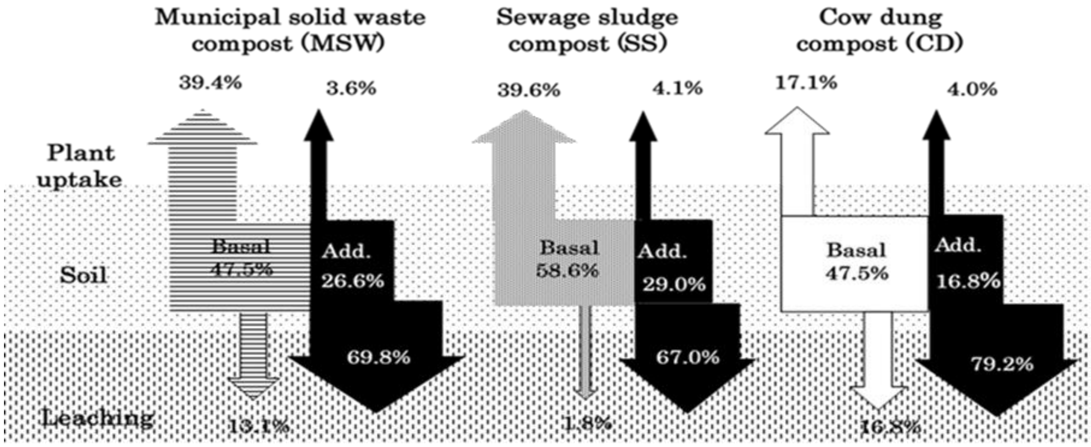

Figure 5. N dynamics of basal fertilizer (Basal) and additional fertilizer (Add.) as influenced by different treatments

Combining the application of organic compost and inorganic fertilizer to crops has been shown to be more effective in increasing the yield than an application of either fertilizer type alone [14]. Further, Han *et al.* [17] showed that a blend of chemical fertilizers and compost could increase the mineralization rate of compost-N. In this study, after adding urea, crop yield (shoot length) of the MSW treatment improved. However, ^{15}N data in our study indicated that most N uptake was derived from compost-N rather than urea-N. This result is consistent with above-described studies.

IV. Conclusion

In Vietnam, the amount of organic waste (including municipal solid waste, sewage sludge, and waste of agro-industrial origins) generated has increased rapidly over time. Most of these waste streams are deposited in landfills or are incinerated, creating unnecessary environmental burden. Therefore, there is widespread interest in recycling these organic-waste products into soils that are low in organic matter. In the present study, the effects of MSW were evaluated and compared with SS, CD, and traditional chemical fertilizers (urea-based N). Using compost as a basal fertilizer and urea as additional (amendment) fertilizer, the agronomical efficiency of using MSW as fertilizer was found to be equivalent to efficiencies of SS and chemical fertilizers, and more than the efficacy of CD as fertilizer. The order of N uptake derived from compost was as follows: MSW = SS > CD. Meanwhile, N leaching decreased in the following order: MSW = CD > SS. The difference in N leaching rates between MSW and SS may depend on the type of raw material and/or the composting technique. In an on-going study we are conducting, we intend to clarify this. We are assessing the quality of fertilizers labeled as organic fertilizer made from various feedstocks in Vietnam. Additionally, we are applying various methods of composting to coffee husks, aiming to find a suitable technique for establishment of a recycling approach.

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