Influences of applying biosolids on the characteristics of five alkaline soil series and biomass of switchgrass

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Abstract
Biosolid (BS) contains abundant in organic matter and nutrients. In order to investigate its positive and negative effects after land application, a pot experiment was conducted using five alkaline soil series amended with different proportions of BS. Amendments of BS efficiently improved the pH value to the neutral levels and significantly increased the contents of organic carbon (OC) and available nutrients in soils, the dry weight (DW) of switchgrass (*Panicum virgatum* L.) also increased. BS significantly increased the electrical conductivity (EC) and concentrations of copper (Cu) and zinc (Zn) in soils.

Key Words
Biosolid, copper (Cu), switchgrass, zinc (Zn)

Introduction
Land-filled and incineration are the two major methods of treating BS produced by wastewater treatment plants. However, because of the limitation of land uses in Taiwan and the enrichment of nutrients and OC in BS, land application of BS seems to be a feasible method in the future. Results of previous studies show that the application of BS increased the yield of barley (Vlamis *et al*., 1985; Gardiner *et al.,* 1995) because of the high content of nutrients in BS. Switchgrass, the test crop used in this study, is primary distributed in central and eastern America and it can be further used to produce biomass energy. The objective of this study is to assess the effect of BS on the soil characteristics and the biomass of switchgrass when BS was applied to five alkaline soils.

Methods and Materials
Sampling and Analysis of soil and BS
Five major soil series from cropped lands in Changhua county and Kaohsiung county were used in this study: Chunliao series (Cl), Lukang Series (Lu), Taikang series (Tk), Tapais series (Tp), and Wanho series (Wa). The collected soil samples were air-dried, ground, and passed through a 10-mesh sieve. The basic characteristics analyzed were pH value (water: soil = 2: 1; Thomas 1996), available Ca, Mg, K, and Na (Mehlich, 1984), OC (Nelson and Sommers, 1996), EC (Rhoades, 1996), and the total concentration of Cu and Zn (EPA/Taiwan 2002). The BS was collected from a wastewater treatment plant located in central Taiwan. After pretreatment and except for pH value (water: soil = 5: 1), the same characteristics as for soils were measured.

Incubation
The four treatments of this study included (a) control (BS-CK): without applying BS, (b) BS-2%: applying 20 g of BS per kilogram of mixture of soil and BS, (c) BS-5%: applying 50 g of BS per kilogram of mixture of soil and BS, (d) BS-10%: applying 100 g of BS per kilogram of mixture of soil and BS. One kilogram of each mixture was added into a rectangle (length 22 cm x width 15 cm x height 5 cm) and then placed in a thermostatic chamber at 20 ℃. After incubation for three months, the soil samples were air-dried, ground, passed through 10-mesh sieves, and analyzed as described in section 2.1.

Pot experiment
A pot experiment was carried out in the phytotron, the air temperature was controlled (day/night = 30/25^{o}C). A uniform mixture of 30 g of incubated soil sample and 70 g of quartzose sand was added into each pot (10 cm in diameter and 6.5 cm in height) with three replicates. The quartzose sands were passed through 20 mesh sieves and desalted with diluted HCl and deionized water to remove contaminants. One hundred seedlings of switchgrass, one week after germination, were planted in each pot and added deionized water

two times per day. Plants were harvested after growing for 30 days, rinsed with tap water to remove adhered soils, and then washed with deionized water to avoid interference. The DW were determined after oven drying at 70°C for 48 hours. Plant tissues were ground, digested using H_2SO_4/H_2O_2 method (Harmon and Lajtha, 1999), and then Cu and Zn concentrations in the digestant determined with an atomic absorption spectrometer (Perkin Elmer, AAnalyst 200).

Results and Discussion

Basic characteristics of soil and biosolid

Except for sandy clay loam Tk, the texture of Cl, Lu, Tp, and Wa was the same (sandy loam). They were all alkaline soils (pH ranged from 7.20 to 7.91) with low EC (0.1-0.8 dS m^{-1}) and moderate OC (0.2-3.4%). The initial concentration of Cu and Zn was less than 40 mg kg^{-1}. The used BS has abundant available P (962 mg kg^{-1}), available K (202 mg kg^{-1}), and OC (29.4%). Its pH value was 4.90 and EC (11.9 dS m^{-1}) was more than the threshold (4 dS m^{-1}) for an alkaline soil. The total concentration of Cu and Zn in BS was 241 and 1,460 mg kg^{-1}, respectively.

Effect on the soil characteristics and DW of Switchgrass

Among the five soils, the highest content of OC (3.32%) was in Lu and Cl was the lowest (0.28%). Relative to CK, the content of OC for Tp and Cl was significantly increased when the BS application rate was more than 2% ($p < 0.05$). BS also increased the OC in Wa, Tk, and Lu, but its effect was only statistically significant compared with CK when the applying rate was more than 5% or 10% (Figure 1a). Because of the higher content of available P in the BS (962 mg kg^{-1}), the available P in the five soils significantly increased even when the application rate was 2%. The five tested soils were all alkaline soils and their pH values were in the range of 7.20-7.91. Because the BS used in this study exhibited strong acidity (pH 4.90), the application of even 2% of BS significantly decreased pH to neutral levels (Figure 1b). The pH values after amending with BS were more suitable for the growth of most plants compared with BS-CK. Higher EC and higher concentrations of Cu and Zn were found in the BS especially for Zn. The application of BS significantly increased the EC and total concentration of Cu and Zn in the soils ($p < 0.05$). The EC values of the five soils were all less than 0.75 dS m^{-1} without amending with BS, however, they significantly increased to the levels of 0.50-2.5 after amending with BS ($p < 0.05$) (Figure 1c). The highest EC value was obtained in Lu treated with 10% of BS. The initial concentrations of Cu and Zn of the tested soils were all less than 50 mg kg^{-1} which can be regarded as non-polluted soils according to the monitoring standards (200 mg Cu kg^{-1} and 600 mg Zn kg^{-1}) of EPA Taiwan. Significant increases were found after treatment with BS, the final concentrations of Cu and Zn were however all less than 80 and 40 mg kg^{-1}, respectively.

Effect of BS on the DW of Switchgrass

The pH value of Tp and Cl was 7.91 and 7.63, respectively. Seedlings of switchgrass grown in Tp treated with BS-CK and BS-2% and Cl treated with BS-CK died possibly as a result of the unsuitable pH values. The application of BS increased the DW of switchgrass grown in five alkaline soils (Figure 1d). According to the experimental results in section 3.2, the pH value change to the neutral levels and the contents of OC and available nutrients significantly increased after amending with BS. The DW of switchgrass consequently increased.

Conclusion

The application of BS enhanced the contents of OC and nutrients in soil and, the growth and yield of switchgrass grown in five alkaline soils. However, the amount of BS applied should be controlled because of its quite high EC and contents of Cu and Zn.

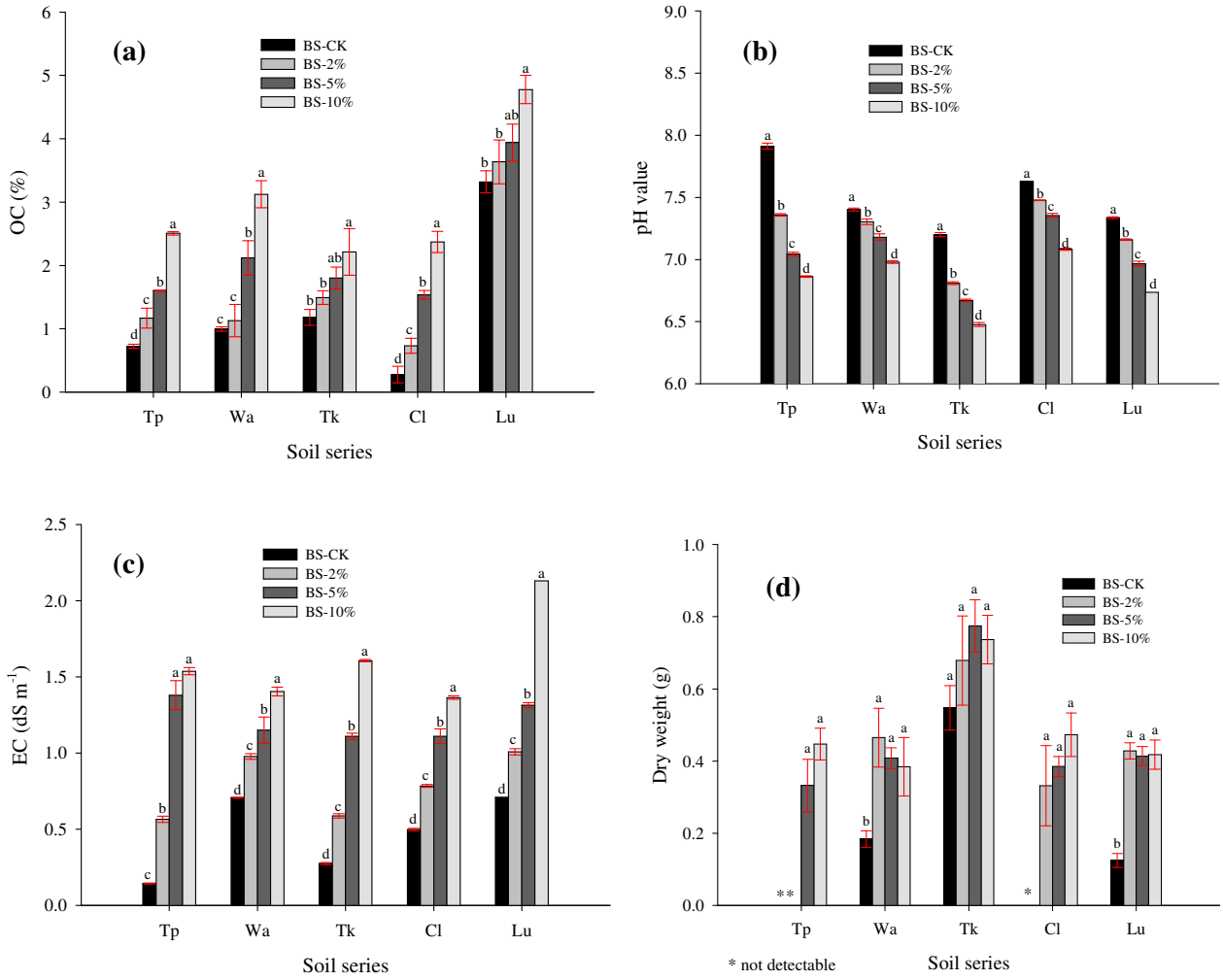

Figure 1. The effects of applying different proportions of biosolid on the (a) organic carbon content, (b) pH values, and (c) electrical conductivity of five alkaline soils and on the (d) dry weight of switchgrass.

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