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Original Paper

Evaluation of Efficiency to Plant Growth in Horticultural Soil Applied Biochar Pellet for Soil Carbon Sequestration

JoungDu Shin†, YoungSu Choi, Eunjung Choi,
MyungSook Kim, JeongWook Heo*

Department of Agricultural Environment, National Institute of Agricultural Science, RDA
Department of Agricultural Engineering, National Institute of Agricultural Science, RDA*

토양 탄소 격리 적용을 위한 바이오차 팰렛 혼합 상토를 사용한 작물 재배 효율성 평가

신중두†, 최용수, 최은정, 김명숙, 허정욱*

국립농업과학원 농업환경부, 국립농업과학원 농업공학부*

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ABSTRACT: Objective of this experiment was to evaluate efficiency of application of biochar pellet in case of application of soil carbon sequestration technology. The treatments were consisted of control as general agricultural practice method, pellet(100% pig compost), biochar pellets with mixture ratio of pig compost(9:1, 8:2, 6:4, 4:6, 2:8) for comparatives of pH, EC, NH_4-N and NO_3-N concentrations, and yields in the nursery bed applied biochar pellets after lettuce harvesting. The application rates of biochar pellet was 6.6g/pot regardless of their mixed rates based on recommended amount of application (330kg/10a) for lettuce cultivation. pH in the nursery bed applied different biochar pellets after lettuce harvesting was only increased in the treatment plot of pig compost pellet application, but decreased in 4:6 and 2:8 pellet application plots. However, EC was observed to be not significantly different among the treatments. NH_4-N concentration was only increased in the treatment plot of pig compost pellet application, but NO_3-N concentrations were decreased as compared to the control. Yields in the treatments of 9:1, 8:2 and 4:6 biochar pellet application plot were increased from 9.5% to 11.4%. Therefore, this biochar pellet application might be useful for soil carbon sequestration and greenhouse gas mitigation in the agricultural farming practices because it was appeared to be a positive effect on lettuce growth.

Keywords: Biochar pellet, carbon sequestration, growth responses, lettuce

초 록: 본 실험의 목적은 토양탄소 격리 기술을 개발하기 위한 바이오차 팰렛 시용에 따른 토양의 이화학성 변화 및 작물 수량 효과에 대해 평가하는 것이다. 처리는 일반적인 영농 방법으로서 대조구, 돈분 팰렛, 바이오차와 돈분 퇴비 혼합 비율별 바이오차 팰렛 시용구 (9:1, 8:2, 6:4, 4:6, 2:8)로서 구성되어 있다. 바이오차 팰렛의 사용량은 상추 재배를 위한 추천 시용량 (330kg/10a)기준으로 혼합 비율에 관계없이 6.6 g/pot이었다. 상추 수확 후 상토의 pH, EC, 암모늄태 질소의 농도 변화를 분석하였다. 실험 결과로서 pH는 대조구와 비교하여

† Corresponding author(e-mail : jdshin1@korea.kr)

돈분펠렛 처리구에서 증가하였지만, 바이오차 펠렛 처리구(4:6 및 2:8)에서 감소하였다. EC는 처리구간에 유의차를 보이지 않았다. 암모늄태 질소 함량은 단지 돈분 펠렛 처리구에서 증가하였지만, 질산태 질소는 모든 처리구에서 감소하였으나, 상추 수량은 대조구와 비교하여 바이오차 펠렛 처리구(9:1, 8:2 및 4:6)에서 9.5%에서 11.4%가 증가하는 것으로 나타났다. 그러므로 바이오차 펠렛 시용은 상추생육에 저해요인으로 작용하지 않고, 오히려 긍정적으로 나타남으로서, 작물 재배에 있어서 바이오차 펠렛을 시용하게 되면 토양 탄소격리 및 온실가스 완화를 위해서 유용하다고 생각된다.

주제어: 바이오차 팰렛, 탄소 격리, 상추

1. Introduction

Biomass is composed of carbon rich materials including all plants, animals, nutrients, excrements and bio-waste from households and industries[1)]. Unused or discarded biomass residues from agricultural areas are potential energy resource, but at same time can be a source of GHG emissions, causing a significant environmental problem. Potential energy production from crop and animal residues is globally estimated to be about 34 EJ (exajoule $=10^{18}$ joules) out of a total 70EJ[2)]. In Korea, it is estimated that over 50 million tones of organic wastes are produced every year in agricultural sector out of over 80 million tones[3)]. The interest of biomass in resource-poor country such as Korea is therefore increasing.

Biochar is the carbonaceous product obtained by heat treatment of biomass under limited or no oxygen (pyrolysis or liquefaction technology). Biochar has recently gained attention for its potential, when cooperated with soil to improve soil fertility and to store carbon removed from the atmosphere by plants. Biochar's positive effects on the soil ecosystem, including both plants and microbes, have been proposed to derive either directly from nutrients within biochar itself or indirectly its ability to absorb and retain nutrients [4),5)].

Biochar may improve soil chemical properties as increase of soil pH and cation exchange capacity (CEC), and enhancement of nutrient retention. Bio-char may improve soil physical properties as increase of soil pH and cation exchange capacity (CEC), and enhancement of nutrient retention. This has provided the incentive to study the effects of bio-char applications on soil N cycling[4-7)]. Number of studies has reported that adding bio-char to soils may increase net nitrification rate[8)] and alter N availability for crops[9)]. Bio-char addition has altered N transformation following the application of N containing substances such as bovine urine, swine manure, green waste compost and bio-solid[10-12)]. The interaction between bio-char and soil N cycle is acknowledged, and there are several comprehensive reviews recently published on this topic[13-14)]. Applying N fertilizers in combination with bio-char has been proposed for improving temporal synchrony between crop N demand and soil N availability, enhancing N use efficiency and reducing environmental impacts. However, the mechanism by which bio-char influences such processes is not well understood. The reduction in N_2O emissions after biochar soil amendment was first reported in a greenhouse experiment by Rondon *et al*.[15)]. They found that N_2O emissions were decreased by up to 50% for soybean and by up to 80% for grass growing in a low fertility oxisol from the Colombian savanna. Since then, the interest in bio-char as a N_2O mitigation strategy for agricultural soils has been continuously increasing, and the number of studies evaluating N_2O emissions from biochar treated soils has risen exponentially.

Carbon inputs and outputs are affected by management and by two biotic processes-production of organic matter in the soil and decomposition of organic matter by soil organism. The soil carbon sequestration by biochar application is determined by the soil carbon residual differences between compost treatments only and cooperated with biochar after harvesting corn. For effect of biochar application, it found that applications of aerobic swine digestate, cow compost, and pig compost could sequester C by 38.9%, 82.2% and 19.7% in soil, respectively, when biochar from rice hulls was cooperated with soil[16]. However, there is litter information available on biochar pellet that can control nutrient release rate from pellet to soil throughout the growing season and to provide most of nutrients to plant without leaching loss[17].

Therefore, this study was conducted to evaluate growth responses of lettuce and physicochemical properties of soil to biochar pellet application regarding to its soil carbon sequestration for agricultural practices.

2. Materials and Methods

Biochar pellet made through the machine with those combination materials which were completely mixed with instrument Photo. 1. The combination ratios of biochar and pig compost were 9:1, 8:2, 6:4, 4:6 and 2:8. Treatments were consisted of control, 100% of pig compost pellet, and biochar pellets with mixture ratio of pig compost; 9:1, 8:2, 6:4, 4:6 and 2:8.

For bioassay test with biochar pellets, the seed was sowed in the nursery plate with inserting pit moss in the glass house at December 15, 2015. The crop was lettuce (Lactuca sativa, L., cv. 'Romaine'), and the plants were transplanted into pots inserting mixtures of rice and horticulture bed materials at 30 days after seedling. The pot size was $\Phi 18 \times 30$ cm, and loading amount of bed materials was 2.25 kg per each pot. Application amount of fertilizer and compost were based on 0.115-0.29-0.12 g/pot and 6.68 g pot^{-1} as recommended application amount for lettuce cultivation. The dropping irrigation was set on 2 min. for one time irrigation period with 3 times per days. Chemical properties of soil used in this study were presented in Table 1.

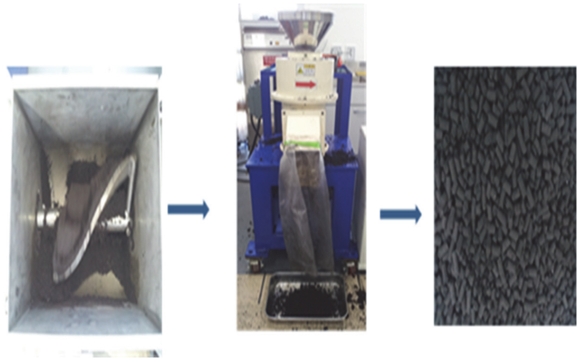

Photo. 1. Paradigms of processing the biochar pellets for this experiment

Soil samples were collected after harvest of lettuce. The samples were dried and passed through 2 mm sieve and then stored in refrigerator (4℃) until analyzing the soil chemical properties.

Soil chemical properties were analyzed pH, EC, and total nitrogen (TN), total carbon (TC), total organic carbon (TOC) and total inorganic carbon (TIC) by TOC analyzer (Elementar Vario EL II, Germany). Total carbon combustion temperatures was 950℃ and WO_3 was used as the catalyst. The carbonate was destroyed completely by using 2M HCl until there were no bubbles and fumes, and then samples were dried for another analysis. Thus TOC content was obtained. TIC was determined by the difference between TC and TOC. Soil extract solutions with 2M KCl (1:5, soil: extractant ratio) were analyzed NH_4-N and NO_3-N contents by Auto Analyzer Technician II.

Table 1. Physicochemical properties of nursery bed before experiment

pH	EC	TC	TOC	TN	C/N ratio	NO_3-N	NH_4-N
(1 : 5)	dS m^{-1}	-----------%-----------				mg kg^{-1}	mg kg^{-1}
5.04	4.85	1.34	1.39	0.13	13	41.51	44.24

For the plant responses, yield was measured at every harvesting time.

3. Results and Discussions

Growth responses of lettuce in the pots to application of biochar pellet with different combination rates of pig compost were described in Fig. 1. It was observed that yield in both pellet (100% pig compost) and 6:4 treatment plot (biochar: pig compost) was not significantly different with the control which was applied pig compost. Yield of the other treatments were higher than the control. Especially yield in the treatment plot of 9:1 biochar pellet was higher at 11% than the control. This implies that application of biochar pellet which is more than 20% of biochar content for lettuce cultivation should be sequestered soil carbon and mitigated the greenhouse gases without reduction of lettuce yield compared with the control. Also, application of biochar in the corn field for carbon sequestration was significantly not occurred the damage of corn growth and enhanced the fresh biomass weight of corn except PC (pig compost) treatment[9]. Shin *et al*.(2014) indicated that plant height and fresh ear yield of corn were not significantly different among

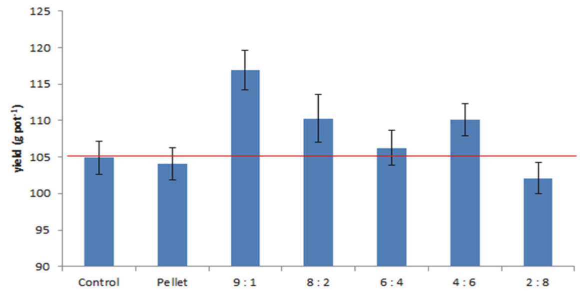

Fig. 1. Comparisons of yield in the nursery bed applied biochar pellets with different ratios of pig compost mixed after lettuce harvesting.

the biochar treatments[16].

Comparisons of pH and EC in the nursery bed applied biochar pellets with different ratios of pig compost mixed after lettuce harvesting were described in Fig.2. pH in the plots applied with pellets (100% pig compost), 8:2 and 6:4 was higher than the control. It shown that application of biochar pellet was contained more at 60% of biochar to enhance soil pH. However, pH in the plots treated with 9:1, 4:6 and 8:2 biochar pellet was lower than the control. EC in the all the treatments did not significantly different with the control except 8:2 biochar pellet application plot.

Comparisons of NH_4-N and NO_3-N concentrations in the nursery bed applied biochar pellets after harvesting were described in Fig. 3. NH_4-N concentrations in the

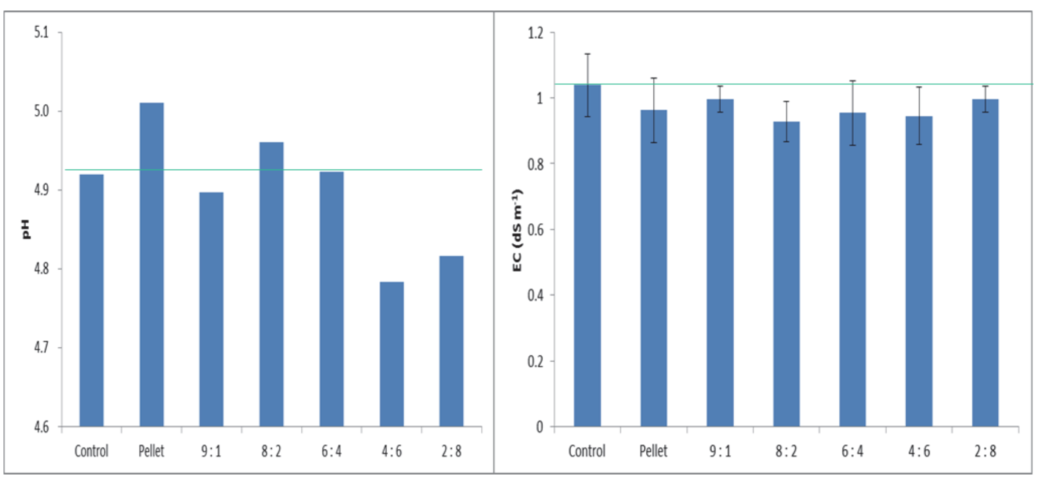

Fig. 2. Comparisons of pH and EC in the nursery bed applied biochar pellets with different ratios of pig compost mixed after lettuce harvesting.

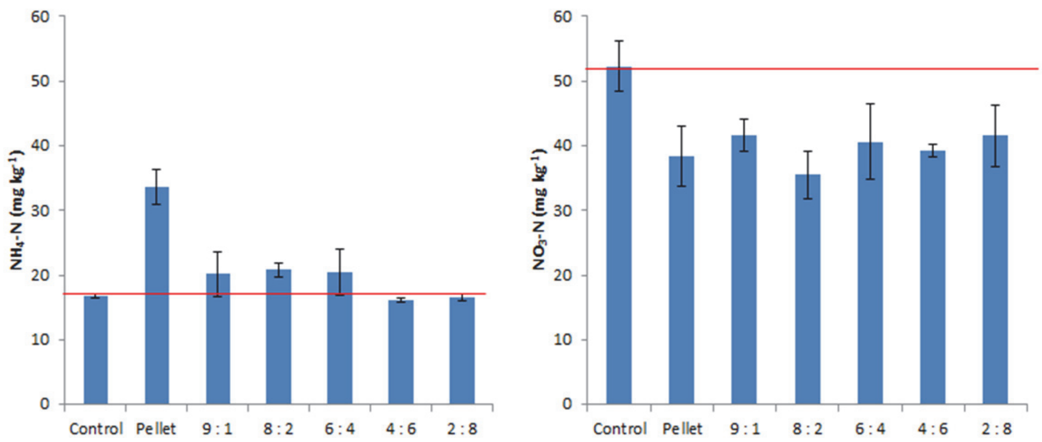

Fig. 3. Comparisons of NH_4-N and NO_3-N concentrations in the nursery bed applied biochar pellets with different ratios of pig compost mixed after lettuce harvesting.

horticultural soil applied biochar pellets were not significantly different among treatments except pellet (100% pig compost) and 8:2 biochar pellet application plots relative to the control. It implied that nitrogen nutrient may not be lacked for lettuce cultivation even if put 10% of pig compost combination into the pot. However, NO_3-N concentrations in the all treatments did not significantly different compared with the control. It is considered that NO_3-N concentrations will be came from the nursery bed by different ratios of biochar pellets because NO_4-N did not nitrifying into NO_3-N[18].

4. Summary

For physicochemical properties of nursery bed after harvesting, pH in the nursery bed applied different biochar pellets after lettuce harvesting was only increased in the treatment plot of pig compost pellet application, but decreased in 4:6 and 2:8 pellet application plots. However, EC was observed to be not significantly different among the treatments. NH_4-N concentration was only increased in the treatment plot of pig compost pellet application, but NO_3-N concentrations were decreased as compared to the control. Yields in the treatments of 9:1, 8:2 and 4:6 biochar pellet application plot were increased from 9.5% to 11.4%. Therefore, this biochar pellet application might be useful for soil carbon sequestration and greenhouse gas mitigation in the agricultural farming practices because it was appeared to be a positive effect on lettuce growth.

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