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Original Paper

Characteristics of Nutrient Release of Biochar Pellets through Soil Column during Rice Cultivation

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토양 Column을 이용한 벼 재배 시 바이오차 펠렛의 양분용출 특성

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ABSTRACT: This experiment was conducted to investigate nutrient leaching and mobility through soil column for application of biochar pellet during rice cultivation. For nutrient leaching through soil column experiment, it was also consisted with four treatments as control, 100% of pig manure compost pellet (PMCP), biochar pellet (pig manure compost:biochar, 6:4)(BP), and slow release fertilizer (SRF). For experimental results, it was observed that NH_4-N concentration in the leachate was gradually decreased at pick of 35 days and NO_3-N concentration was highest from 60 to 98 days after transplanting. PO_4-P concentration in the leachate was shown to be lowest in the PMCP and BP. K concentration in the leachate was highest in the control, but lowest in SRF. For mobility of nutrient in soil depths, it shown that NH_4-N concentrations were highest from 40 to 60cm and did not significantly different among treatments except the control. It was observed that the deeper depth, the higher concentration for NH_4-N concentrations, but for PO_4-P concentrations the deeper depth, the lower concentration. And also PO_4-P concentration was highest in the control. For K mobility in soil, its pattern was appeared to be approximately same between the control and PMCP, and between BP and SRF. Therefore, it might be potential to be applied biochar pellet to reduce mobility of plant nutrients for rice cultivation.

Keywords: Biochar pellet, mobility, plant nutrients

초 록: 본 연구는 토양 칼럼에 벼를 재배하면서 바이오차 펠렛처리에 따른 침출 수 및 토양 중의 작물 양분 이동 동태를 구명하기 위해 수행하였다. 칼럼 실험을 위한 시험구 처리는 돈분퇴비처리구를 대조구, 100% 돈분퇴비 펠렛구, 바이오차 펠렛 그리고 완효성비료 처리구로 구성되어있다. 연구 결과로서, 침출수 중의 NH_4-N의 농도는 이양후 35일을 정점으로 점차적으로 감소하였으며, NO_3-N의 농도는 이양 후 63-98일 사이에 가장 높게 관측 되었다. 침출수 중의 돈분 팰렛 및 바이오차 팰렛 처리구에서 PO_4-P의 농도가 가장 낮게 나타났다. 침출수 중의 K의 함량이 대조구에서 가장 높게 보인 반면, 완효성비료 처리구에서 가장 낮게 나타났다. 토양의 깊이별 NH_4-N의 농도는 40-60cm사이가 가장 높게 났으며, 돈분 팰렛 처리구를 제외하고 처리구 간에 유의차가 없었다. 또한 토양 깊이가 깊을수록 NH_4-N의 농도가 높게 관측 되었다. 반면에 PO_4-P의 농도는 완효성비료

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처리구를 제외하고 토양깊이가 깊을수록 낮게 나타났다. 대조구에서 PO_4-P의 농도가 가장 높았다. 토양중의 가리의 이동 패턴은 대조구와 돈분 퇴비 펠렛구, 그리고 바이오차 펠렛구와 완효성처리구가 비슷한 것으로 나타났다. 그러므로 벼 재배 시 바이오차 펠렛을 시용함으로써 식물 양분 이동에 의한 손실을 줄일 수 있는 것으로 사료 되다.

주제어: 바이오차 펠렛, 이동, 작물 양분

1. Introduction

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

Biochar is the carbonaceous by-product obtained by thermal treatment of biomass under limited or no oxygen with using pyrolysis or liquefaction technology for biomass conversion. Biochar from thermal conversation technology has recently gained attention for its potential ability to improve soil fertility and to store soil carbon with addition of biochar into soil. Biochar's positive effects on the agro-ecosystem have been proposed to derive either directly from nutrients within biochar or indirectly from its ability to adsorb and retain nutrients[4]. When biochar is cooperated into soil application of organic or inorganic fertilizers are still needed to improve crop yield. Many studies investigated the value added biochar for soil amendment which suggested the blending of biochar with nutrient rich manures, compost or poultry litter before soil application[5,6]. The incorporation of biochar with sludge composite into land application was found to significantly reduce nitrogen loss[5]. However, storage, transportation and soil application of biochar became challenging because biochar is brittle, and has wide particle size distribution with low density. Blue Leaf Inc. reported a loss as high as 30% by wind-blown during handling, transport to the field and soil application of biochar. In particular, 25% of the biochar applied was lost during spreading to the field[7]. And 20-53% of biochar incorporated into soil was also lost by surface runoff during intense raining events[8]. Pelletization of biochar is one way to reduce transportation and handling costs and significantly decrease loss of biochar during soil application[9]. Biochar pellet has been used as an alternative to biomass pellet mostly heating material[10]. For soil application, lignocellulosic and poultry litter feedstocks were blended, pelletized and slowly pyrolyzed to produce biochar pellets[11]. However, there is litter information available on biochar pellets that can control the nutrient release rate from biochar pellet as slow release fertilizer. Slow release fertilizer is required to gradually release nutrients to soil through the growing season and to provide most of the nutrients to plant without leaching and denitrification losses[12], which can, furthermore, reduce loss in farmer profit and minimize potential damage to the environment[13].

Therefore, objective of this study was conducted to investigate nutrient leaching and mobility through soil column for application of biochar pellet during rice cultivation.

2. Materials and Methods

Biochar from rice hull and pig compost were purchased from local farming cooperative society. Physiochemical properties of biochar pellets and pig compost used were presented in [Table 1]. The experiment was consisted with 4 different treatments such as the control, 100 % pig manure compost pellet (PMCP), biochar pellet (4:6; biochar: pig manure compost rate) (BP) which loaded with solution of chemical reacted fertilizers and slow release fertilizer (SRF).

Biochar pellet made through the machine with the combination materials which were completely mixed using the agitator with spraying water [Fig. 1].

The size of soil column was ∅10cm x 60cm. Each column was loaded with 100g of sea sand at bottom and then placed 4.2kg of paddy soil. After this step, 1.68 kg of soil was mixed with each treated material and then placed in to soil column. The water was slowly poured into soil column and then transplanted rice into the soil column. The application amount of compost and biochar pellet was 2,500 kg ha^{-1}, and chemical fertilizer was applied at 85-45-57 kg ha^{-1} (N-P-K) based on recommendation rates of NIAS. All compost and biochar pellet, phosphorous and potassium were treated as basal application. Water was poured into soil column at required amount every day [Fig. 2]. But BP was applied only based on N 90 kg ha^{-1}, and SRF on N 90 kg ha^{-1} and 2,600 kg ha^{-1} of pig manure compost. All compost and biochar pellet, phosphorous and potassium were also treated as basal application. Nitrogen fertilizer was applied with 3 separations as basal, and 2 additional applications.

The leaching water sampled at 14 days intervals until harvest, and soil after harvest were analyzed with NH_4-N, PO_4-P and K. The collected water was filtered using whatman #2 filter paper, analyzed directly with nitrogen content, and stored in a refrigerator until analysis of PO_4-P and K using UV spectrophotometer (ST-Ammonium, C-Mac, Korea).

3. Results and Discussions

3.1. Leaching patterns of plant nutrients

Urea is widely used as nitrogen fertilizer worldwide

Table 1. Characteristics of biochar and pig compost used[1)]

	pH	EC ($dS\ m^{-1}$)	TC[1)]	TOC[1)]	TIC[1)]	TN[1)]
			---------------	%	---------------	
Biochar	9.78(1:20)	16.53	56.63	53.30	4.25	0.20
Pig compost	8.77(1:5)	3.40	28.89	25.86	3.02	2.91

[1)] TC; Total carbon, TOC; Total organic carbon, TIC; Total inorganic carbon, and TN; Total nitrogen

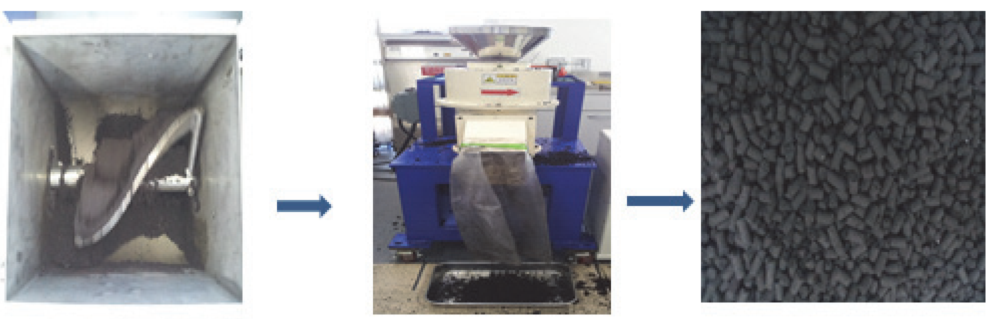

Fig. 1. Processing diagram of biochar pellet with different pig manure compost ratios.

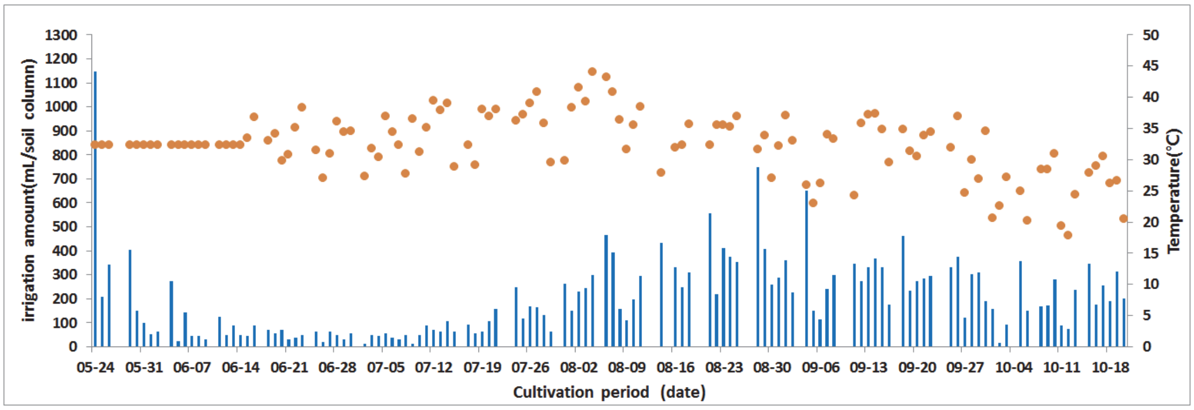

Fig. 2. Amount of water added in the each soil column and average temperature in the glass house during rice cultivation.

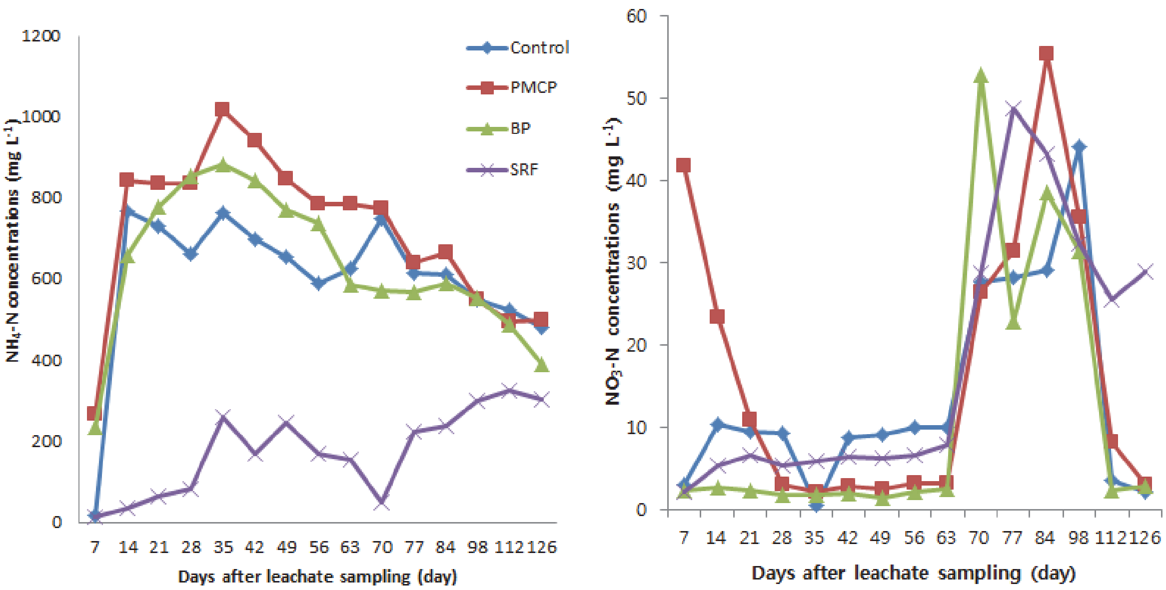

Fig. 3. Leaching pattern of nitrogen from soil column for different treatments during rice cultivation.

that release N rapidly to soil, from which only 40% is recovered by plant and 60% is lost by different ways[14] and maximum loss was estimated as evaporative loss (26.5-29.4%) that contributed to greenhouse gas. Therefore, a controlled release N fertilizer is best way to minimize the N_2O emission from soil[15]. For NH_4-N in the leachate, it was observed that NH_4-N concentration in the leachate was gradually decreased at pick of 35 days, but NO_3-N concentration was highest from 60 to 98 days after transplanting [3]. It was appeared that NH_4-N concentration was observed to be lowest in leachate of SRF's treatment, but NO_3-N concentration in the leachate of BP's application was lowest during rice cultivation [Fig. 3]. Shin et al.[16] observed that NH_4-N adsorbed fast at combination rate(9:1) of biochar pellet in both the pseudo first and second order kinetics. It was further observed that the more biochar contains in the biochar pellet, the greater adsorption of NH_4-N.

A large amount of nitrogen and phosphate fertilizer is applied in the soil every year to increase the soil fertility. The present consumption of rock phosphorous is over one million tons yearly[17] as fertilizer. Excessive

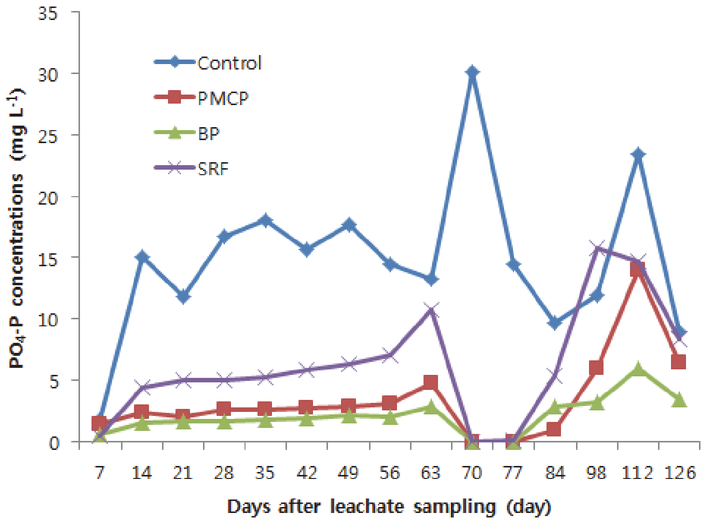

Fig. 4. PO_4-P concentrations in the leachate from soil column for different treatments during rice cultivation.

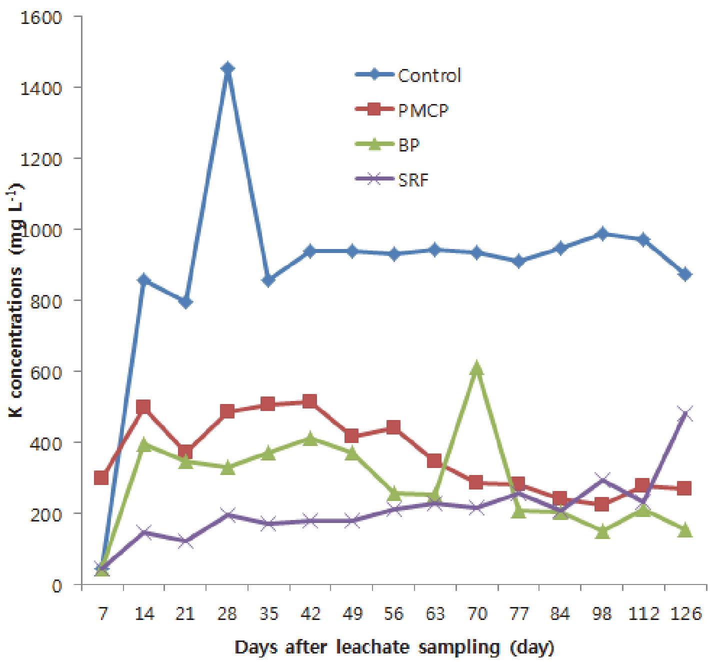

Fig. 5. K concentrations in the leachate from soil column for different treatments during rice cultivation.

phosphorous in lakes and ponds is major cause of eutrophication, which occurs on a global scale, and destroys the ecosystem[18]. It was described that PO_4-P concentration in the leachate was shown to be lowest in the BP application, but was highest in the control [Fig. 4]. This might be contributed to originally have high phosphorus content in the pig manure compost, and also pelletization of material used might be change the releasing characteristics of plant nutrient.

K concentration was highest in the leachate from the control, but lowest in the SRF. However, K concentration in the leachate from soil column applied biochar pellet (4:6) was lower than the PMCP [Fig. 5].

3.2. Mobility of major plant nutrient in soil

For mobility of nutrient in soil depths, it shown that NH_4-N concentrations were highest from 40 to 60cm and did not significantly different among treatments except the PMCP [Fig. 6]. It was observed that the deeper depth, the higher concentration for NH_4-N concentrations, but for PO_4-P concentrations the deeper depth, the lower concentration.

For the PO_4-P concentrations, it was appeared that the greater concentration the deeper soil. PO_4-P concentration was highest from 40 to 60cm of soil depth regardless of treatments [Fig. 7]. It was not significantly different at 40-60cm of soil depth among the treatments.

For K mobility in soil, its pattern was appeared to be approximately same between the control and PMCP, and between BP and SRF. However, it was observed that the deeper soil depth. the lower concentrations had except 40-60cm of soil depth in SRF [Fig. 8].

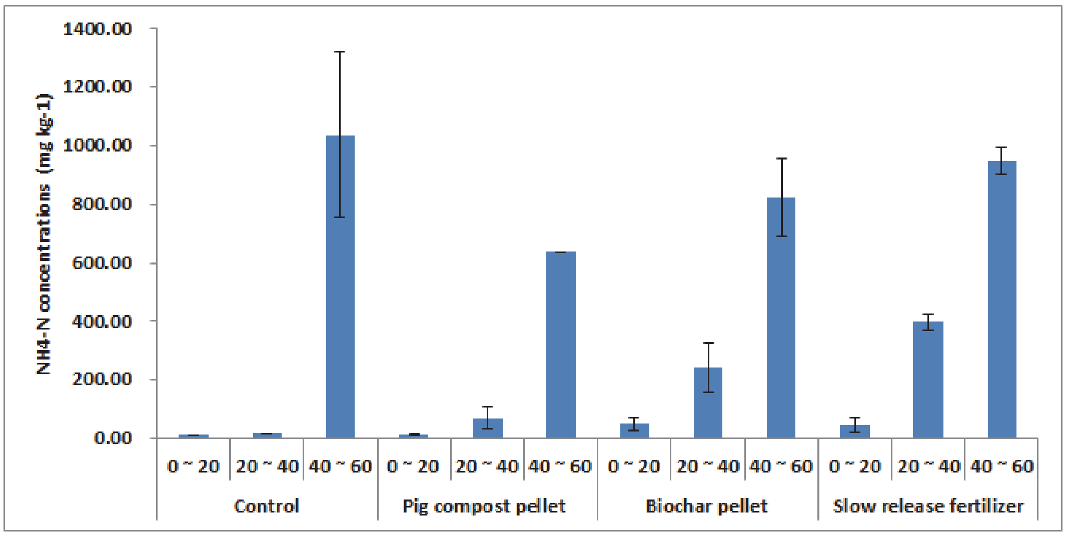

Fig. 6. Mobility of NH_4-N from soil column for different treatments during rice cultivation.

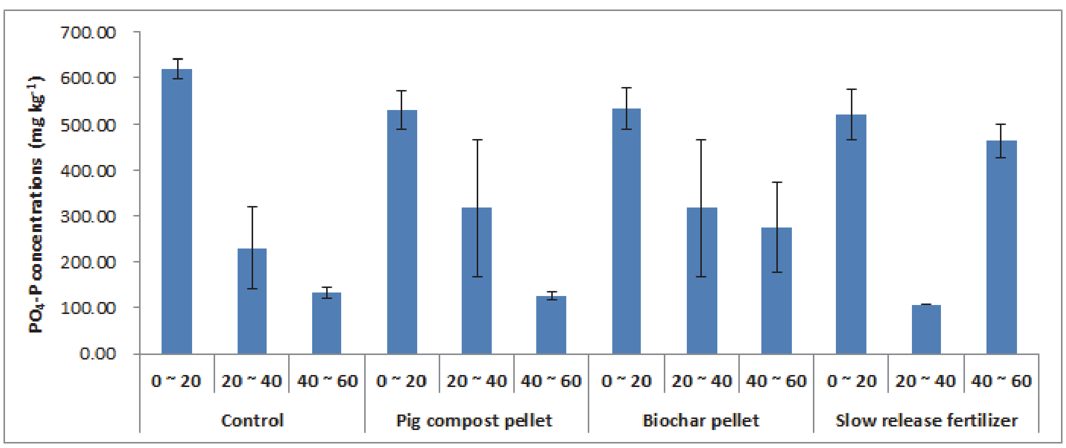

Fig. 7. Mobility of PO_4-P from soil column for different treatments during rice cultivation.

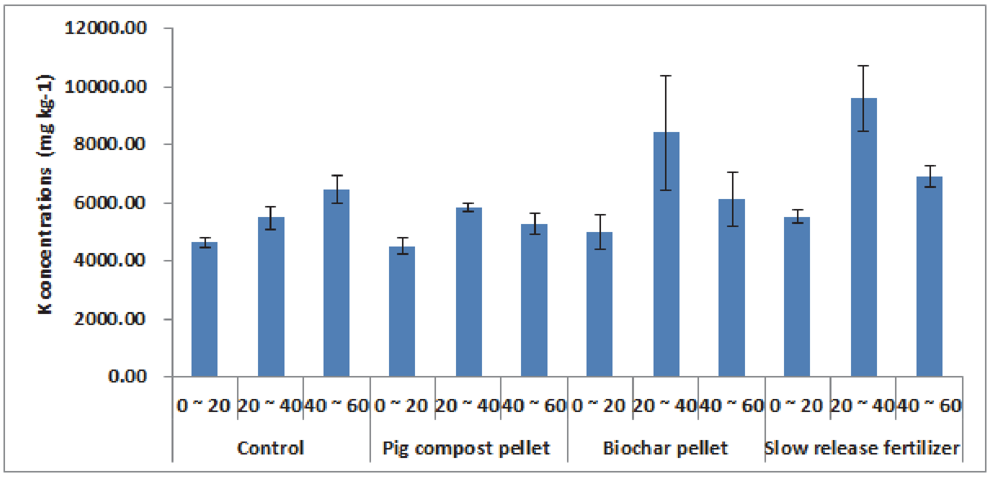

Fig. 8. Mobility of K in soil column for different treatments during rice cultivation.

4. Conclusions

NH_4-N concentration in the leachate was gradually decreased at pick of 35 days and NO_3-N concentration was highest from 60 to 98 days after transplanting. PO_4-P concentration in the leachate was shown to be lowest in the PMCP and BP. K concentration in the leachate was highest in the control, but lowest in SRF.

For mobility of nutrient in soil depths, it was observed that the deeper depth, the higher concentration for NH_4-N concentrations, but for PO_4-P concentrations the deeper depth, the lower concentration. And also PO_4-P concentration was highest in the control. For K mobility in soil, its pattern was appeared to be approximately same between the control and PMCP, and between BP and SRF. Therefore, it might be potential to be applied biochar pellet to reduce mobility of plant nutrients for rice cultivation.

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