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Effect of Bioagent-added Organo-mineral Nitrogen Fertilizer on Total Nitrogen, pH, and Chrome Content in Lowland Paddy

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Abstract

Rice field soil quality in Rancaekek decreases gradually due to textile waste water to irrigation source. One of the heavy metal contaminant is chrome (Cr). As an effort to reduce Cr residue, bioagent-added organomineral nitrogen (abbreviated as BaON) fertilizer consisted of the mixture of urea, zeolite, activated charcoal, and plant compost enriched with bioagent (*Bacillus subtilis*) was added as a slow release fertilizer. This paper studied the effect of BaON fertilizer formulation towards total nitrogen content, pH and total Cr content in Rancaekek paddy soil. The experiment was designed in Randomized Block Design with six treatments and five replicates, consisted of: 0 (control), 150; 200; 250; 300; and 350 kg ha^{-1}. The result showed that the application of BaON fertilizer increased soil total nitrogen content and pH, and decrease Cr residue in Rancaekek paddy field soils. Application of 350 kg ha^{-1} of BaON fertilizer gave the highest increase of total nitrogen in 60 days after transplant (0.11%), while 300 kg ha^{-1} of BaON gave the highest increase in pH (6.18), and the application of 250 kg ha^{-1} of BaON gave the highest reduction of chrome (16.15 mg kg^{-1}) in Rancaekek soils. This study suggests that application of Urea-zeolite-activated charcoal and bio-agent inoculated compost application could minimize Cr contaminated waste in the long-run.

Keywords: *Bacillus subtilis*, heavy metal, soil ameliorant, bioremediation

1. Introduction

The quality of productive agriculture system in Indonesia has been steadily decreasing due to environmental pollution. The pollution source also varies, ranging from agrochemical inputs such as synthetic pesticide, fertilizers, plant growth hormone, to heavy metals used in the manufacturing process of neighboring industrial areas. The discharge became a problem particularly because it was untreated prior to its release to the environment (Yaseen and Scholz, 2019).

Rancaekek was a well-known rice producer in the 1980s (Komarawidjadja, 2017), but after the land use conversion in the area, the quality of soil and water utilized for agricultural irrigation has depleted. Rancaekek experienced massive land use conversion from agriculture production area with rice as a main commodity,into textile production area. This shift has lead copious amount of pollutant to be discharged to the environment. The amounts of documented heavy metals detected in Rancaekek riverbank soil in 2017 were 174.7 mg l^{-1} of chrome, 92.2 mg l^{-1} of elemental mercury, and 4.0 mg l^{-1} of arsenic above the environmental safety level of industrial waste. Cikijing river is one of the polluted rivers used as agricultural irrigation source in four villages in Rancaekek areas: Linggar, Jelegong, Sukamulya, and Bojongloa village (Sutono and Kurnia, 2013). Trace level of heavy metal is present in water and may be essential for living organisms (Benamar and Zitouni, 2013), but high concentration may adversely impact the environment.

One of the heavy metals contained in the polluted wastewater is chrome (Cr). Cr came from fabric dyes (Chavan, 2011) and harmful for human health. Poisoning symptoms includes nausea, abdominal pain, respiratory problems, kidney and liver damage, accumulation of this metal can lead to death. In plants, Cr inhibits the availability of nitrogen, phosphate, potassium, and other primary nutrients. High Cr concentration can decrease the germination percentage of paddy up to 60% (Nagarajan and Ganesh, 2014).

Immobilization is one of the ways to reduce heavy metal availability in the environment. A method that could be used is through the addition of biological and chemical agents to bind or reduce heavy metals availability in the soil. Bio-agent added organomineral nitrogen (BaON) fertilizer is a modification of urea-based nitrogen fertilizer, zeolite, activated charcoal, and compost with a bio-agent that has a role as a slow release fertilizer and heavy metals absorbent. Zeolite addition in nitrogen fertilizer made the ammonium released by the fertilizer entrapped in by zeolite structure (Ippolito, Tarkalson and Lehrsch, 2011) and will be discharged back to the soils when the availability of nitrogen is low. Addition of activated charcoal is known as heavy metals adsorbent, due to the characteristics of charcoal that could selectively adsorb ions (Larasati et al., 2016). Addition of bio-agent on the fertilizer can improve the effectiveness of nutrient supply

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and reduce heavy metals in soils. This research aims to find out the effect of BaON in various doses on total nitrogen value, pH value, and degradation of heavy metal Cr on polluted soils.

2. Materials and Methods

Paddy field soil were obtained from Jelegong Village, Rancaekek (6°57'41.67"-6°58'52.29"S, 107°46'54.41-107°48'10.13"E). Paddy variety used in this study was Inpara 9 Agritan variety, product of Indonesian Ministry of Agriculture. Urea (Pupuk Kujang, Cikampek, Indonesia), Zeolite, and Technical Grade Activated Charcoal were ground and sieved through 30 mesh pass to obtain 0.6 mm particle size. Compost used were plant compost with 26:1 C/N Ratio and 22% relative humidity level, and were finely ground and sieved through 70 mesh pass to obtain 0.210 mm particle size. Prior to fertilizer formulation, *Bacillus subtilis* was inoculated in Nutrient Broth (Himedia, Mumbai, India), and kept under ambient temperature (25-28ºC) on 125 rpm rotary shaker for 72 hours and reached 10^7 cfu population density. Urea, zeolite, activated charcoal, compost, and bioagent inoculant (*B. subtilis*) were mixed with 50:20:20:10 rations, respectively.

The experiment was conducted from January to July 2019 at Faculty of Agriculture, Universitas Padjadjaran experimental greenhouse, Ciparanje village, Jatinangor (6°54'59.0"S, 107°46'18.2"E). An Inpara 9 seedling were transplanted in a polybag contained 20 kg of Jelegong village paddy field soil and fertilizer were added in accordance to the treatment doses. Paddy soil were watered once daily. The experimental design used was Randomized Block Design, with one control and five doses of treatments; A= 0 (control), B = 150 kg BaON, C = 200 kg BaON, D = 250 kg BaON, E = 300 kg BaON, F = 350 kg BaON, each treatment was replicated five times.

At 20, 40, and 60 days after BaON fertilizer treatment, soil quality parameters such as total nitrogen content, soil pH, and chrome content were analyzed. Obtained data were analyzed with Analysis of Variance (ANOVA). Differences detected will be analyzed further by Tukey’s post test with 5% confidence level. Data were processed by SPSS version 22 software.

3. Results and discussions

3.1. Initial Soils Analysis

Jelegong village soil was analyzed to obtain the information of total nitrogen value, pH value, Cation Exchange Capacity (CEC), and heavy metals content. The analysis revealed that total nitrogen content was 0.09% (very low), medium-high CEC (39.89 cmol kg^{-1}) and neutral pH (7.05). Heavy metals analysis showed that the chrome content was 38.84 ppm (polluted), and lead content was below the threshold (17.58 ppm).

3.2. Total Nitrogen

Nitrogen is one of the nutrients needed by plants in a large quantity. Nitrogen in soil is very mobile and could be easily lost by leaching or volatilization. BaON fertilizer application is one of the ways to supply nitrogen in soil continuously. Application of BaON fertilizer notably increased soil total nitrogen and continuously supplied nitrogen up until 60 days after application in the polluted paddy soil (Table 1). At 20 days after transplant (DAT), Treatment C (dosage 200 kg ha^{-1}) gave significant difference compared to Treatment B (dosage 150 kg ha^{-1}) and Treatment E (dosage 300 kg ha^{-1}). There was a significant difference between BaON on treatments compared to the control in 60 days after transplant (DAT).

Table 1. Bio-agent Added Organomineral Nitrogen (BaON) Fertilizer Effect on Total Nitrogen on Soils

Treatment	Total Nitrogen (%)		
	20 DAT*	40 DAT	60 DAT
A	0.12ab	0.09a	0.08a
B	0.11a	0.09a	0.10ab
C	0.14b	0.11a	0.09ab
D	0.12ab	0.10a	0.09ab
E	0.12a	0.10a	0.09ab
F	0.12ab	0.11a	0.11b

*DAT: Day after transplant

In Table 1, in 40 DAT observation all treatments show non-significant differences and lower nitrogen content compared to 20 DAT. This could be caused by the slow release trait from the fertilizer, therefore on 40 DAT, the nitrogen was released at lower rate in longer time. At 60 DAT, treatment F (350 kg ha^{-1}) with a total nitrogen of 0.11% displayed the highest amonium content at the end of vegetative phase.

The zeolite addition on fertilizer can minimize nitrogen loss in ammonium form. Zeolite has high absorbency power on ammonium. Released ammonium in soil will be reabsorbed by zeolites and released again in low ammonium conditions, which allows preservation of nitrogen in soils (Larasati et al., 2016). Zeolites and activated charcoal addition on the formulation could provide nitrogen slowly. Zeolites with 75-80% dosage of N could produce rice with the same amount as conventional fertilizer, therefore it could reduce the usage of synthetic fertilizer up to 25% (Jufri and Rosjidi, 2012).

3.3. Soil pH

There was a significant difference between the control and BaON treatments on 20 and 60 days after transplant (Table 2)

Table 2. Bio-agent Added Organomineral Nitrogen (BaON) Fertilizer Effect on pH on Soils

Treatment	pH		
	20 DAT	40 DAT	60 DAT
A	5.86ab	5.61a	5.43a
B	5.89ab	5.54a	6.13bc
C	5.73a	5.65a	5.98b
D	5.71a	5.75a	6.18c
E	5.93b	5.60a	6.12bc
F	5.94b	5.77a	5.98b

On 20 DAT, Treatment E (300 kg ha^{-1}) and Treatment F (350 kg ha^{-1}) was significantly different to Treatment C (150 kg ha^{-1}) and Treatment D (200 kg ha^{-1}), but was not significantly different to control and Treatment B (150 kg ha^{-1}). The highest value found on Treatment F (dosage 350 kg ha^{-1}) with 5.94 and categorized as slightly acidic.

All treatments were not significantly different to each other at 40 days after transplanting. The highest pH value was found on treatment F with 5.77 and categorized as slightly acidic. All treatments, except treatment D pH decreased at 20 DAT. This is very likely due to the increased nitrification in soil due to the release of hydrogen ions post nitrogen fertilization (Lu *et al.*, 2012). At 60 DAT, soil pH value on BaON treatments gave significant effect compared to control. Treatment D increased pH value at 60 DAT. This allows less application of the fertilizer if the case of soil pH enhancement, as the pH value of Treatment D was not significantly different compared to treatments with higher dose (E and F). BaON contain urea that may trigger nitrification, which produce H^+ ions. Soil acidity value is affected by the existence of hydrogen ions (H^+). The higher H^+ ions on the soils, the higher the acidity of the soils.

Zeolite and activated charcoal addition on the fertilizer can amend soils pH value, as zeolite contains alkaline bases such as K^+, Na^+, and Mg^{2+} that could replace H^+ in adsorption complex, which led to the rise of pH value. In higher pH, metal ions react spontaneously and form metals-hydroxide bonds (Maulana et al., 2017). BaON application increased and maintained soil pH, which eventually impacted the nutrient availability on soils.

3.4. Heavy Metals Solubility on Soils

Statistical analysis showed BaON treatment reduced Cr availability in soil (Table 3). Treatment C displayed the highest chrome immobilization in soil compared to other treatments. Urea application in soil increases nitrate content, an important product used in the nitrification process (Shetty et al., 2019). Chrome solubility reduced due to the reaction between Cr^{3+} and NO_3^-.

Table 3. Bio-agent Added Organomineral Nitrogen (BaON) Fertilizer on Cr Reduction

Treatment	Heavy Metals Cr (mg kg^{-1})		
	20 DAT	40 DAT	60 DAT
A	19.61b	21.85b	21.00b
B	13.10a	17.03a	16.99ab
C	13.55a	18.73ab	16.15a
D	20.15b	20.58ab	19.32ab
E	15.41ab	17.53ab	18.30ab
F	17.59ab	18.27ab	17.36ab

Charcoal and zeolite mixture content can also reduce heavy metals content on polluted soils because of its ability to bind and maintain ions inside its complex. Adsorption by activated charcoal is an effective way to reduce heavy metals (Atmono et al., 2017). This was caused by decreased competition between H^+ and metal ions when the pH value is high, so that heavy metals adsorption process will increase rapidly if compared in lower pH conditions (Akaninwor et al., 2007).

The addition of organic matter in the form of compost may have the primary role in chrome reduction. Compost contains essential nutrient for plants and improves soil health. Compost addition could reduce the availability of heavy metals and improve plant growth and development (Angelova et al., 2010). The utilization of compost (thermophilic or vermicompost) can reduce heavy metal solubility, increasing soil pH value, electrical conductivity, and nutrients in soils (Shreshta et al., 2019).

Bacillus subtillis the microbial strain inoculated in the compost was known for its ability to absorb heavy metals. Several researches showed that *Bacillus subtilis* can reduce heavy metals contamination in a more environmentally friendly manner and as affective as 87% absorption rate towards chrome contaminants (Syed and Chintala, 2015). Besides its chrome-adsorbing abilities, genus Bacillus is also widely known as phosphate solubilizer (Bhakthavatchalu and Shivakumar, 2017).

4. Conclusion

Bioagent-added organo-mineral nitrogen fertilizer application in various concentration has improved the chemical properties of lowland paddy soil. The application improved the total nitrogen, pH, and reduced Cr residue, after 20, 40, and 60 day after treatment. Treatment F was the best treatment to increase total nitrogen, meanwhile treatment D was the best treatment to increase pH value

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