The Use of Humic Acid-Coated Biochar (*Bicomat*) and Plant Spacing on Paddy Plant Production and the Reduction of Heavy Metal Content

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Abstract. This study aimed to find out the use of Bicomat doses and spacing to increase crop production and heavy metal reduction. It was carried out in paddy fields in Karangploso Subdistrict of Malang District from April to July 2022. The study used a Randomized Group Design (RGD), 2 factors and 3 repetitions. The first factor was the dose of Bicomat (B) consisting of B0 = Control (without Bicomat), B1 = Bicomat 10 t ha^{-1}, B2 = Bicomat 20 t ha^{-1}, and B3 = Bicomat 30 t ha^{-1}; the second factor was the planting distance (P) comprising 3 planting distances of paddy plants: P1 = 20 × 20 cm, P2 = 20 × 30 cm, and P3 = 20 × 40 cm. The observed parameters included the plant height, number of leaves, stem diameter, number of saplings, paddy grain weight per plot, and weight of 1000 paddy grains. While the analyzed heavy metal were Pb and Cu. The results showed that the use of BCH doses increased the growth of paddy plants on all observed parameters. The use of a dose of Bicomat of 10–20 t ha^{-1} increased the weight of grain and the weight of 1000 grains of paddy. The use of doses of 10 t and 20 t with a planting distance of 20 × 40 cm showed significant growth. The average weight of dry grain obtained at the doses of 10 and 20 t of ha^{-1} and a planting spacing of 20 × 40 cm amounted to 7.93 and 7.53 kg of plot-1. While in the weight parameter of 1000 grains of paddy, the results averaged out at 32.67 and 34.33 g. The reduction of Pb and Cu metal obtained were 26.23%–58.77% and 56.12%–89.96%, respectively.

Keywords: Biochar · Humic Acids · Rice Plants · Heavy Metal

1 Introduction

Indonesia is classified as a country with a fairly high level of land use and agrochemicals. The problem that arises from these two activities is the low soil product of heavy metal accumulation. The accumulation of heavy metal on agricultural land is currently not

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only taking place in Indonesia but also in other countries experiencing the same thing such as Japan, China, Korea, and Thailand. At present, soil pollution, basically fertilizers and pesticides, becomes a concern for the parties, particularly in agricultural centers. Globally there are more than 20 million ha of land contaminated with heavy metals such as As, Cd, Cr, Hg, Pb, Co, Cu, Ni, Zn, and Se, with high concentrations and has passed the threshold value as required [1].

Cadmium (Cd) and zinc (Zn) contaminants were found in Europe mainly in the roots of food crops which were harvested at 50 mg kg^{-1} for Cd and Zn at 65 mg kg^{-1} [2]. In southern China, Pb levels found in rice reach more than 0.2 mg kg^{-1} [3]. This finding needs to be watched out for because it harms health if consumed continuously. [4, 5] stated that the Pb levels found in several agricultural centers in East Java already went beyond the threshold of 2.26 mg kg^{-1}. This point, if not addressed immediately, is ensured to reach the food chain which further affects human health. The heavy metal contaminating the soil is very difficult to degrade, and cleaning is hard. Conventionally heavy metal cleaning costs quite a lot. In addition to being polluted, the land used as an agricultural area is low in productivity. The results of soil analysis were C-organic 1.73%, N 0.13%, P 0.64, K 0.03, and KTK 6.00 cmol kg^{-1} [6, 7]. The use of appropriate soil-conditioning materials will speed up the improvement of the soil. One of the soil-conditioning materials that many people nowadays apply is biochar.

Biochar is a soil conditioner that has a fairly good adsorption capacity and has the potential as a source of slow-release fertilizer [8]. The biochar combined with urea fertilizer is known to reduce the rate of nutrient release and increase fertilizer efficiency. Molded biochar is very important as a fertilizer carrier [9]. Biochar is known to be a good conditioner for physical characteristics, but not for chemistry. Humic acid coated with biochar will be effective in use in the short and long term. So far, research on biochar as an amendment material has been carried out quite a lot [10, 11]. In the same way, it is with the use of humic acids. However, the studies were carried out individually, and not many of the two have been combined into one as a soil conditioner.

As a conditioning agent, in the short-term biochar is effective in improving physical properties, but new chemical properties will be found sometime in the future [12]. The conditioning of the chemical properties can be performed with the use of humic acids. Humic acids are nutrient supplements in the form of organic substances that have complex molecules and can stimulate and activate soil microorganisms for biological and physiological processes. The role and function of humic acids can also be referred to as soil conditioners [13]. The success of the extraction and isolation of humic acids from various types of organic matter has an impact on efficient and effective soil conditioning methods.

The use of biochar coated with humic acid is intended for the biochar to be able to improve the physical properties, while the humic acid can improve the chemical properties. Biochar, apart from being a soil conditioner, also plays a role in controlling heavy metals.

This study was conducted with the aim of testing various doses of Bicomat (Biochar Coated Humat), henceforth this term is used) and paddy planting distances against the growth, production, and reduction of metal to ensure safe food products for consumption.

2 Research Methods

The study was conducted in Karangploso Subdistrict of Malang District, East Java Province, at an altitude of ±450 m above sea level. The soil and plant analysis was carried out in the laboratory of the Faculty of Agriculture of Tribhuwana Tunggadewi University and the laboratory of the Soil Science of UPN Veteran of East Java. The study was conducted from April to July 2022, using Randomized Group Design (RGD), two factors, and three repetitions. The first factor was the dose of Bicomat (B) consisting of B0 = Control (without Bicomat), B1; Bicomat 10 t ha^{-1}, B2; Bicomat 20 t ha^{-1}, and B3; Bicomat 30 t ha^{-1}. The second factor was the planting distance (P) comprising P1 = 20 × 20 cm, P2 = 20 × 30 cm, and P3 = 20 × 40 cm. The observed parameters included the plant height, number of leaves, stem diameter, number of saplings, the weight of paddy grain per plot, and weight of 1000 grains. While the analyzed heavy metal The characteristics of biochar, such as its high surface area and specific groups, as well as its alkaline properties, are important in the absorption of heavy metal The characteristics of biochar, such as its high surface area and specific groups, as well as its alkaline properties are important in the absorption of heavy metal. were Pb and Cu. The plant observation was conducted weekly until the harvest.

Bicomat was made from biochar materials produced in the bioenergy laboratory of the Tribhuwana Tunggadewi University by way of pyrolysis, while humic acids were obtained from the extraction process of organic matter in the chemistry laboratory. The isolation of humic compounds used the Stevenson method (1982). The bicomat making was carried out by mixing the biochar and humic acid in a ratio of 1:1 as a whole. 1 g of adhesive polymer was added to the mixture which was further molded as bicomat in the form of granules. The finished bicomat was then applied to the plants as a treatment.

After harvesting, the roots, stems and leaves of the plant are separated and washed under running water to wash off the dirt. Next, they were put in the oven at 60 °C for 72 h. After drying, they were finely ground to be analyzed. A total of 2 g of fine sample was then dissolved with 10 mL of HNO3 and HCLO4 and heated to a remaining volume of 2 mL; after that, it was reheated gradually with distilled water until the liquid became clear (pure white). The clear liquid was then mixed with distilled water and then filtered. The filtered results were then measured for Pb and Cu contents using an atomic absorption spectrophotometer (AAS). The soil analysis included pH (H2O), C-organic (Walkey-Black), N (Kjedahl), P (Olsen), K, and KTK (Ammonium Acetate pH 7.0). The heavy metal weight as the contaminants were analyzed for Pb and Cu.

3 Results and Discussion

The results of soil analysis showed that the soil in the study location was neutral soil pH (6.34). The content of the organic matter and nitrogen was in a moderate condition (2.66% and 0.27%). The potassium content in the area was in a very low condition of 0.725 cmol kg^{-1}, while the phosphorus was in a fairly high range of 68.77 mg kg^{-1}. Both heavy metals of Pb and Cu were in the range exceeding the threshold values, 16.73 mg kg^{-1} and 80.23 mg kg^{-1} respectively (Table 1). The high intensity of land use was a contributing factor.

Table 1. Average Demand for Cayenne Pepper in Pare Main Market, Kediri Regency

Parameter	Value	Criteria
pH	6.34	Neutral *)
Organic-C (%)	2.66	Medium *)
N-total (%)	0.27	Medium *)
K2O5 (cmol kg^{-1})	0.725	Very low *)
P2O5 (mg kg^{-1})	68.77	High *)
Pb (mg kg^{-1})	16.73	Critical value **)
Cu (mg kg^{-1})	80.23	Critical value **)

*) Soil research center. **) National Standarization Agency

Fig. 1. Observation of plant growth

The results of the analysis showed that the use of Bicomat and planting distances for paddy plant growth indicated significant growth (Fig. 1). These results showed that the use of Bicomat in the paddy plants showed significant growth at various doses (0; 10; 20 and 30) of t of ha^{-1}. Statistically, there were no interactions in the various treatment combinations, but separately it was seen that a dose of 20 t of ha^{-1} showed better growth than the other dose. The vegetative parameters of the plant with the trend growth from the observation period indicated excellent plant growth.

Table 2. The average results of the analysis of the variety of Bicomat use and the planting distance of paddy plants

Treatment	Number of saplings	Grain weight/plot (kg)	Weight of 1000 grains (g)
B0J1	23.13 ab	5.50 ab	27.00 ab
B0J2	26.80 bc	6.33 bc	28.67 ab
B0J3	28.07 bc	7.33 bc	30.67 bc
B1J1	20.93 ab	5.77 ab	26.33 ab
B1J2	23.33 ab	7.37 bc	29.33 ab
B1J3	38.60 c	7.93 c	32.67 bc
B2J1	23.67 ab	6.30 b	31.33 bc
B2J2	25.00 ab	6.60 bc	32.33 bc
B2J3	25.40 ab	7.53 bc	34.33 c
B3J1	22.47 ab	4.30 ab	26.67 ab
B3J2	22.80 bc	5.83 ab	29.33 ab
B3J3	26.47 b	6.50 bc	31.67 bc
BNT	4,96	1,58	3,367

Note: The numbers followed by the same letter do not differ markedly

The results of the analysis of the variety of vegetative growth of plants showed that the use of Bicomat at various doses with planting distances gave a real interaction with the parameters of the number of saplings, the weight of the paddy grain per plot, and weight of 1000 paddy grains. The results of the variance analysis are presented in Table 2. The Bicomat dose treatment of 10 t ha^{-1} with a planting distance of 20 × 40 cm (B1J3) showed a significant number of saplings. The average number of the highest saplings was achieved in each treatment of B0J3 (28.07), B1J3 (38.60), B2J3 (25.40), and B3J3 (26.47). These figures were the highest of all observed doses of Bicomat.

The next thing was the parameters of the weight of the paddy grain and the weight of 1000 grains of paddy These two parameters showed that the use of doses of 10 t and 20 t with a planting distance of 20 × 40 cm indicated significant growth. The average weight of the dry grain obtained at doses of 10 and 20 t of ha^{-1} and planting distances of 20 × 40 cm was 7.93 and 7.53 kg of plot-1. The same thing is seen in the weight parameters of 1000 paddy grains on average of 32.67 and 34.33 g.

The results of the analysis of heavy metal of Pb and Cu after the planting showed a significant decrease in the heavy metal in the soil. Figure 2 shows that bicomat use could reduce the soil Pb between 26.23–58.77% while that of Cu was between 56.12–89.96%. This shows that the use of bicomat in addition to being able to increase growth and crop production could mobilize the heavy metal.

The soil characteristics at the study site are in low condition. One of the indicators of soil fertility is the content of organic matter. The high level of organic matter will function as a buffer for soil fertility. However, in this study, the obtained C-organic content was in a moderate condition (2.66%) so it was difficult to support the plant

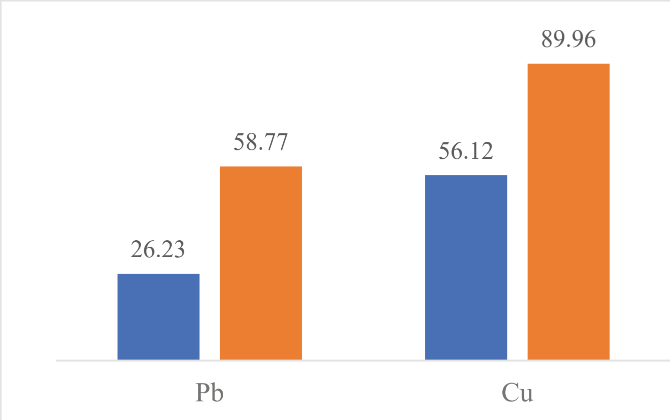

Fig. 2. Reduction of heavy metal of Pb dan Cu (%)

growth. This figure is not much different from the research conducted by [14] studying the paddy fields in Jombang, where the C-organic content is in the range of 1.39–3.69%. This shows that the paddy fields that have been cultivated for a long time need attention. The low C-organic obtained is thought to be because the remnants of paddy yields were immersed in the soil as the organic matter was not completely decomposed, considering that the paddy fields were in anaerobic conditions, the decomposition was slow. Soils that are often flooded are in a reductive state so the decomposition of organic matter lasts for a long period of time.

The use of bicomat for soil improvement proves to be able to increase plant growth. This can be seen from the parameters of plant height, the number of leaves, and stem diameter that are visible showing a good growth trend. There was no statistical interaction in various treatment combinations, yet separately it was proven that a dose of 20 t of ha^{-1} showed better growth than that of another dose. This was indicated by the growth parameters measured in each observation period. In general, the plants aged 8 weeks after planting (WAP) show growth, particularly the plant height, number of leaves, and stem diameter. The use of bicomat in paddy plants looks very effective to push ahead the plant growth. The paddy plants are those that have the adaptability to grow quite well. Plant adaptability can affect crop production [15]. The use of bicomat is one of the ways to adapt to the soil environment conditions so that the paddy plants can grow properly. The use of biochar in addition to being a soil conditioner also increases the efficiency of N and K fertilization. Its use is very suitable, especially in tropical areas for agricultural sustainability [16]. Biochar is also a living habitat of soil microbes. In such conditions, if coated with humic acid which is also a nutrient like microbes, the speed of conditioning will be faster. The use of bicomat for paddy cultivation in this study was proven to increase paddy growth and production. In addition to the role of soil improvement, the planting distance has a role in plant growth as well. Plant spacing can provide planting flexibility in the absorption of nutrients, water, and solar radiation.

The use of bicomat at various doses with spacing provides a real interaction with the parameters of the number of saplings, the weight of the grains per plot, and the weight of 1000 grains. The use of a bicomat dose of 10 t ha^{-1} with a planting distance of 20 × 40 cm is the best treatment. This is thought to be due to the fact that a much wide planting distance will provide wider growing space to generate more saplings. A wide row spacing will result in a high number of saplings. A wider planting distance will provide the flexibility for sunlight to penetrate the bottom of the plant so that it is effective in the photosynthetic process. When photosynthesis takes place well, the distribution of the photosynthesis results will also be better. On the contrary, tight planting distances result in competition in the fight for sunlight, water, and nutrients that affect plant growth and crop production.

Another role of Bicomat besides soil conditioning will further trigger the absorption of heavy metal in paddy plants. The paddy plant is a type of remediator plant that can absorb heavy metal. The heavier metal gets absorbed in polluted soils, the less presence of heavy metal in the soils. This study showed that the use of bicomat could trigger the absorption of heavy metal and then deposit it in the roots. The results of the study showed that there was a reduction in heavy metals of Pb and Cu ranging from 26, 23–58.77% and 56.12–89.96%, respectively. The absorbed heavy metal was further deposited in the root as phytoextraction. [17] suggest that soil amendments such as biochar, humic acids, or biochar enriched with humic acids are effective in reducing the availability of heavy metals of Cd, Cu, Pb, and As. This amendment lowers the interchangeable fraction and increases the oxidation and residual fractions.

These results are in line with the results of other researchers' studies finding that biochar can remediate Pb between 18.8–77.0%, and Cu about 20% [18], [19]. These results suggest that the application of humic acid-coated biochar is effective in paralyzing heavy metals in polluted soils. The decrease in Pb and Cu absorption in plant tissues occurring due to the immobilization process (physisorption, chemisorption, and precipitation) of heavy metal by biochar and humic acids is really effective in inhibiting the activation of plants into metal and reduces the absorption of metal by plants. The immobilization of heavy metal by biochar will convert the heavy metal into a more stable and less toxic form. However, the presence of humic acids encourages the formation of humic acids of Pb and Cu water to complement each other, and prevents the formation of Pb and Cu hydroxide, thereby increasing the availability and mobility of soil Pb and Cu.

The results of the study showed that biochar-coated humic acids consistently decreased the concentration of soil Pb and Cu. The reduction of soil Pb was greater than that of soil Cu. This means that biochar coated with humic acids is more efficient in stabilizing Pb compared to soil Cu. The characteristics of biochar affect the mechanism of immobilization. The characteristics of biochar, such as its high surface area and specific groups, as well as its alkaline properties, are important in the absorption of heavy metals. The biochar characteristics such as surface heterogeneity, functional groups, and large surface area will stabilize heavy metals by absorbing them on their soil surface and increasing precipitation and surface absorption due to its porous microstructure.

Thus, the use of bicomat as an amendment material is very effective in soil improvement and reducing heavy metals of Pb and Cu. The more heavy metal is reduced in the soil, the safer the plants growing on the soil to be consumed.

4 Conclusions

The use of Bicomat is very effective in increasing the vegetative growth of plants. The Bicomat dose of 20 t of ha^{-1} at a planting distance of 20 × 40 cm can increase paddy production by 7.53 g, while the weight of 1000 grains is 34.33 g. The use of Bicomat can reduce the Pb and Cu contaminants by 26, 23–58.77%, and 56.12–89.96% respectively.

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