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Effectiveness of modified nitrogen fertilizer on soil chemical properties and rice plant growth in the textile industrial area

Abstract. The imbalance of nutrients and heavy metal contamination is a challenge in increasing plant growth surround the textile industry area. This study aimed to determine the effectiveness of the dosage of Biologically Agent N Organo Mineral Fertilizer (Biomix-N) as a fertilizer and an ameliorant in paddy soil contaminated with textile liquid waste. This study used a randomized block design of eight treatments with four replications. Parameters observed were soil chemical properties after application of Biomix-N (Na-ex, total N, EC, Cd, and pH), rice plant growth (plant height and tiller number), Cd concentration in the plant, and relative agronomic effectiveness (RAE). Data analysis used analysis of variance, Duncan's test at a 5% level, regression, and correlation analysis. The results showed that Biomix-N 500 kg ha^{-1} affected the value of EC and total N, while it did not affect Na-ex, Cd, pH and Cd uptake by the paddy plant. Biomix-N fertilization affects the height and number of tillers of rice plants at the age of 70 DAP. Biomix-N fertilization 500 kg ha^{-1} gave an RAE value of 126-176% compared to the control treatment. The total N content of the soil has a high value of coefficient determinant and correlation (R^2= 0.76; R = 0.9) on the growth of rice plants. Applying Biomix-N 500 kg ha^{-1} equal to 300 kg ha^{-1} of urea was an effective dose for paddy soil surround the textile industrial area.

Keywords: Cadmium · Nutrient balance · Soil amendment

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Introduction

Rice is a staple food for the majority of the population in Indonesia. The increase in production is directly proportional to the expansion of the land area for growing rice and increasing the productivity of rice plants (Qurrohman et al., 2023). However, there are challenges in increasing the land area for rice cultivation due to the need for converting paddy fields for other purposes, such as infrastructure, residential, and industrial development. This conversion negatively impacts the available land area and the ecological conditions in the surrounding areas.

According to Afrad et al. (2020), converting paddy fields into industrial areas, particularly for the textile industry, leads to a decline in soil and water quality, as well as the quality and quantity of rice yields. Hossain et al. (2015) found that paddy field soils irrigated with textile waste-contaminated water exhibited increased levels of several elements such as Ca, Mg, Fe, Mn, Cu, and Na, as well as heavy metals like Pb, Cd, Ni, and Cr. The accumulation of these elements in the soil leads to an imbalance in nutrient availability (Parent et al., 2016), increased salinity, and accumulated heavy metals, intensifying abiotic stress in rice plants (Imtiaz et al., 2016).

Efforts to enhance rice productivity on soil polluted by textile waste faced the challenge of addressing nutrient imbalances, reducing heavy metal concentrations, and decreasing salinity.. One of the alternative approaches to tackle these issues is by modifying fertilizers and soil ameliorants (Sudirja et al., 2019).

One approach to remediate polluted paddy fields is by reducing the availability of heavy metals and sodium. Heavy metal in the soil affected N uptake by the plant (Blaudez et al., 2000). An alternative is to use N Organo Bio-agent Mineral (Biomix-N) modified nitrogen fertilizer, which consists of urea with ameliorant ingredients such as zeolite, activated charcoal, and bio-agent compost. Zeolite and activated charcoal act as adsorbents for contaminants, like the heavy metal Cd, and can reduce salinity (Ghasemi et al., 2017; Dosa et al., 2022). In addition, compost enriched with the biological agent *Bacillus subtilis*. Syed and Chinthala, 2015 reported that *Bacillus subtilis* had a maximum biosorption of heavy metal The compost was increase organic matter in the soil and also contributes to the reclamation of polluted land by binding the heavy metals with the negative charge of functional groups of humus substances (Wu et al., 2017; Masykuri and Setyono, 2019). The Biomix-N is formulated to fullfill N nutrient for paddy plant and in the same time decrease heavy metal toxicty.

This study aimed to determine the effectiveness of the dosage of Biologically Agent N Organo Mineral Fertilizer (Biomix-N) as a fertilizer and an ameliorant in paddy soil contaminated with textile liquid waste.

Materials and Methods

The research was carried out in paddy fields (Table 1) in Rancaekek District, Bandung Regency, West Java, with an altitude of ± 676 m asl (6º 58' 10.6" S; 107º 46' 58.7" E). Fertilizer production and soil plant chemical analysis were done at the Soil Fertility and Plant Nutrition, Faculty of Agriculture, Universitas Padjadjaran. This research was conducted from September to November 2019.

Table 1. Paddy soil chemical properties.

	Soil Properties	Unit	Values	Category *
1	pH H_2O	-	6.72	Neutral
2	pH KCl	-	4.98	-
3	C-organic	%	1.5	Low
4	Total-N	%	0.84	High
5	NH_4	%	0.16	Low
6	NO_3	%	0.21	Medium
7	Pb	Ppm	21.66	Low
8	Cd	Ppm	0.04	Low
9	Cr	Ppm	75.44	Polluted
10	Na-ex	%	9.46	Medium
11	Electrical conductivity (EC)	dS/m	1.06	Low
12	Cation exchange capacity (CEC)	cmol(+)/kg	43.32	Very high

*Criteria based on Indonesia Soil Research Institute (2009)

The materials used in this study: rice seeds of the Inpara 9 Agritan variety, urea, activated charcoal, *Bacillus subtilis* enriched compost, zeolite, basic fertilizer SP-36 (1.12 g plant^{-1})and

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KCl (0.56 g plant^{-1}). The formulation used in the manufacture of N Organo Mineral Fertilizer with Biological Agents was urea, zeolite, activated charcoal, compost enriched with *Bacillus subtilis* with ratio 60:20:10:10, respectively. The results of laboratory analysis indicated that the N Organo Mineral Fertilizer (Biomix-N) contained 22% nitrogen, 0.03% P_2O_5, and 0.3% K_2O.

The equipment used in this study were: field equipment (hoes, tape measure, plastic rope, stakes, scissors, shovels, hoes, paper, labels, ticks, manual weeder, plastic samples, rulers and stationery), equipment for making N Organo Mineral fertilizers (granulators, sieves, analytical balances, buckets, stirrers, zip plastic) and laboratory equipment for soil and plant analysis.

The experimental design was a randomized block design (RBD) consisting of eight treatments, and each was replicated four times. The study was examined six-level doses of N organo Mineral fertilizer (Biomix-N), 100% urea treatment, and control (without fertilizer) (Table 2). This present study used a dose of Biomix-N between 250-1500 kg ha^{-1} to determine the effectiveness of low to high doses of Biomix-N.

Parameters assessed included pH, Total-N, electrical conductivity (EC), Na-ex, Cd in the soil, relative agronomic effectiveness (RAE), Cd concentrations in the plant, plant height and tillers at 70 days after transplanting (DAP).

Table 2. Application of N organo mineral fertilizer (Biomix-N).

Simbol	Treatment	Doses of fertilizer (kg ha^{-1})
A	Control Negative	0
B	Control Positive (Urea)	250
C	Biomix-N	250
D	Biomix-N	500
E	Biomix-N	750
F	Biomix-N	1000
G	Biomix-N	1250
H	Biomix-N	1500

This researh was divided in two steps (Figure 1). The first step was soil sampling, in which the paddy soil from textile industrial area were collected to be analyzed. The second step involved the cultivation of paddy plant. The Biomix-N was applicated directly in to the soil seven days before the paddy plant was transplanted.

To assess the impacts of the treatments on pH, electrical conductivity, N-total (Kjeldahl method), Na-ex (Flame photometry), Cd, Cd absorption, plant height and number of tillers, data analysis was conducted using analysis of variance (ANOVA) at α= 5% significance level and Duncan's multiple range test at α= 5%. Pearson correlation analysis was done to examine the relationship between pH, electrical conductivity, exchangeable sodium (Na-ex), total N, and the variables of plant height and tillering. The RAE value was calculated using the following equation (Mackay et al., 1984):

$$RAE = \frac{X_i - C}{X_c - C} x\ 100\%$$

Where:
RAE= Relative Agronomic Effectiveness
Xi = Plant growth fertilized with Biomix-N
Xc= Plant growth fertilized with Urea
C= Control

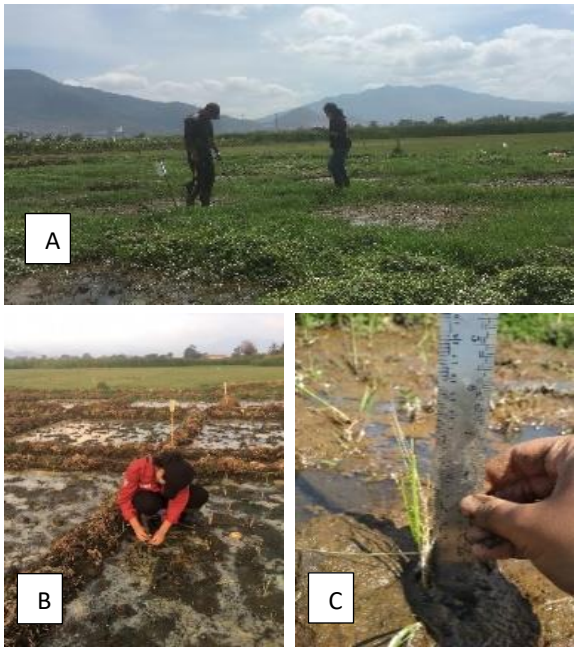

Figure 1. Research stage procedure: (A) soil survey, (B) transplanting paddy plant and (C) measuring plants growth parameter.

Results and Discussion

The effect of Biomix-N fertilizer on the soil pH. The analysis of variance showed that Biomix-N had no effect on the pH of paddy soil ($P > 0.05$). However, when Biomix-N fertilization was applied at doses ranging from 250-1500 kg ha^{-1} or the equivalent of 150-900 kg ha^{-1} urea, along with the inclusion of zeolite and organic matter, it was observed to reduce the adverse impact of urea on soil pH (Figure 2). According to Tong & Xu (2012), the application of urea fertilizer alone can accelerate the decrease in soil pH.

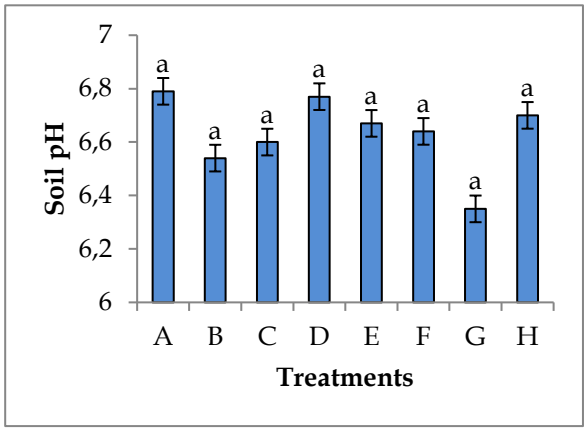

Figure 2. Effect of Biomix-N fertilizer on the soil pH.

The effect of Biomix-N fertilizer on the total N. The results showed that the application of Biomix-N affected the N content in each treatment (Figure 3). The dose of Biomix-N 500 kg ha^{-1} (Treatment D) was significantly different compared to the control without N (A) fertilization. Fertilization with 500 kg ha^{-1} Biomix-N, or equivalent to 300 kg ha^{-1} of urea fertilizer, was not significantly different from the treatment of 250 kg ha^{-1} (B) urea fertilizer, 250 kg ha^{-1} Biomix-N and 750-1500 kg ha^{-1} Biomix-N. The use of Biomix-N fertilizer could save up to 40% of the use of urea fertilizer on rice plant growth. According to He et al. (2002), applying zeolite and compost can increase the N availability in sandy soils. The outcome of this study provides additional information, highlighting that the role of zeolite and compost on clay is similar in enhancing the efficiency of N fertilization. In addition, Aslam et al. (2021) reported that the addition of zeolite and biochar can increase soil nutrient availability.

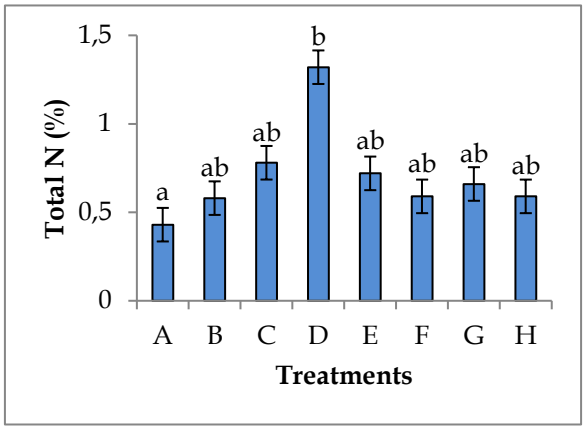

Figure 3. Effect of Biomix-N fertilizer on the soil total N.

Effect of Biomix-N fertilizer on the soil electrical conductivity (EC). The analysis of variance showed that the application of different doses of Biomix-N affected the EC of the soil solution (Figure 4). The dosage of Biomix-N fertilizer 250-1500 kg ha^{-1} was similar compared to the control (urea fertilizer 250 kg ha^{-1}) and without fertilization. The initial chemical analysis (Table 1) of paddy soil in this study showed an EC value of 1.06 dS m^{-1}. This value does not classify the soil as saline soil (Osman, 2013), as soil is considered saline when the EC value exceeds 4 dS m^{-1}. The soil analysis conducted at the end of the vegetative phase demonstrated that applying Biomix-N at doses ranging from 250-1500 kg ha^{-1} was not significantly different compared to the control and without fertilization. These results indicated that fertilization with Biomix-N did not cause salinity in paddy fields.

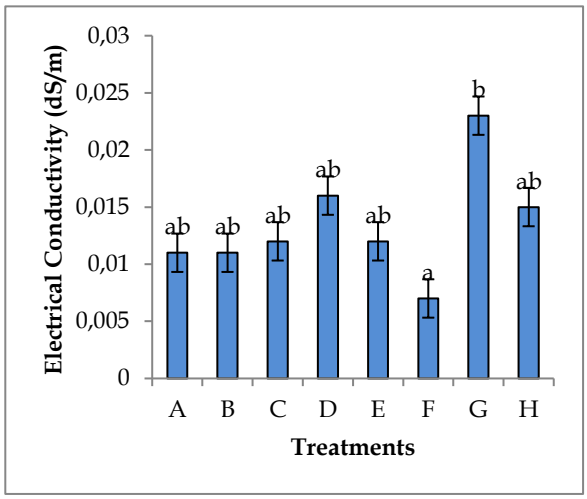

Figure 4. Effect of Biomix-N fertilizer on the soil electrical conductivity.

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The effect of Biomix-N fertilizer on exchangeable soil sodium. The application of Biomix-N fertilization did not show a significant effect on Na-ex (Figure 5). The decrease in Na-ex was not significantly different in the C-H treatment compared to the control (A). The contents of zeolite and compost in Biomix-N did not reduce the Na-ex content significantly. According to Ghorbani et al. (2022), zeolite contains Na^+, which can increase the Na-ex in the soil. The role of compost in reducing Na-ex can only partially solve the problem of soil salinity, but adding compost will improve soil physical properties and other chemical properties (Lakhdar et al., 2009).

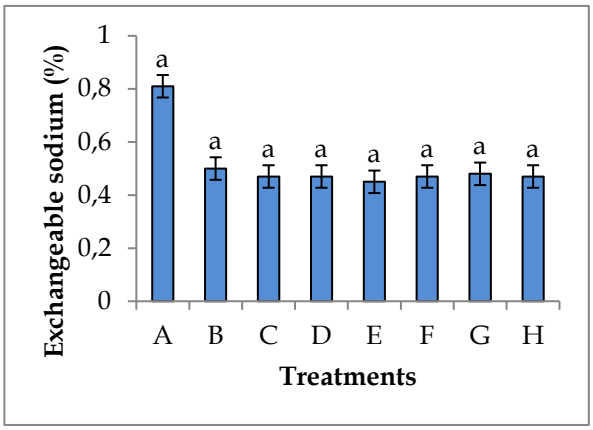

Figure 5. Effect of Biomix-N fertilizer on the soil exchangeable sodium (Na-ex)

The effect of Biomix-N fertilizer on Cd concentration in the soil. Based on the data shown in Table 3, the total Cd content in paddy fields after the treatment was not detected or the amount was lower than 0.01 ppm. This showed that total Cd in the soil decreased compared to initial soil analysis (0.04 ppm).

Table 3 Concentration of Cd in the soil after treatments.

	Treatments	Total Cd (ppm)
A	Control Negative	nd*)
B	Control Positive (Urea)	nd*)
C	Biomix-N 250 kg ha^{-1}	nd*)
D	Biomix-N 500 kg ha^{-1}	nd*)
E	Biomix-N 750 kg ha^{-1}	nd*)
F	Biomix-N 1000 kg ha^{-1}	nd*)
G	Biomix-N 1250 kg ha^{-1}	nd*)
H	Biomix-N 1500 kg ha^{-1}	nd*)

Remarks: nd*): concentration Cd can not be measured because lower than 0.01 ppm

An increased pH value causes a higher metal ion adsorption due to competition with H^+ ions during cation exchange. In addition, the Biomix-N fertilizer contains zeolite and activated charcoal which have a high adsorption of metal ions (Guo et al., 2021).

The effect of Biomix-N fertilizer on Cd absorption by the paddy plant. The high mobility characteristic of Cadmium in the soil easily absorbed by plants. Rice plants accumulated Cd higher than other types of cereals when planted in Soil containing Cd (Gao et al., 2016). Based on the data showed in Table 4, Cd uptake in rice plants after treatment was not detected or the amount was smaller than 0.01 ppm. The concentration of Cd in the soil before treatment and after treatment was still below the Cd tmaximum value of 0.4 ppm (FAO, 2001).

Table 4 Concentration of Cd uptake by paddy plant.

	Treatments	Total Cd (ppm)
A	Control Negative	nd*)
B	Control Positive (Urea)	nd*)
C	Biomix-N 250 kg ha^{-1}	nd*)
D	Biomix-N 500 kg ha^{-1}	nd*)
E	Biomix-N 750 kg ha^{-1}	nd*)
F	Biomix-N 1000 kg ha^{-1}	nd*)
G	Biomix-N 1250 kg ha^{-1}	nd*)
H	Biomix-N 1500 kg ha^{-1}	nd*)

Remarks: nd*): concentration Cd can not be measured because lower than 0.01 ppm

Paddy Plant Growth (Plant Height and Number of Tillering). Based on Figure 6-7, the application of Biomix-N fertilizer affects the plant height and the number of tillers. The Biomix-N fertilization at a dose of 500 and 750 kg ha^{-1} showed a significant difference compared to the treatment without urea fertilization (control negative) on plant height at 70 DAP.

The results also showed there was non significant difference between the application of urea fertilization 250 kg ha^{-1} (B) and Biomix-N fertilizer at doses ranging from 250-1500 kg ha^{-1}. These findings indicated that Biomix-N fertilization can effectively sustain plant growth in conditions of excessive urea fertilization, thereby serving as a soil amendment (Guo et al.,

2021). The increased of rice plants growth was obtained with Biomix-N 250-500 kg ha^{-1}.

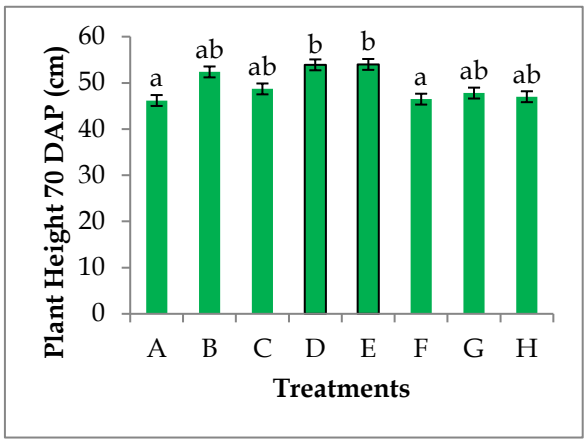

Figure 6. The effect of Biomix-N on paddy plant height 70 days after transplanting (DAP).

Based on figure 6 and 7 Biomix-N 500 kg ha^{-1} was reached the optimum paddy plant height and tillering at 70 DAP. Biomix-N 500 kg ha-1 was equivalent to 300 kg ha-1 of urea fertilizer. Wang et al. (2017) reported that increase N level fertilzer improved plant growth. Nitrogen as a macro element was needed by plant in the large amount.

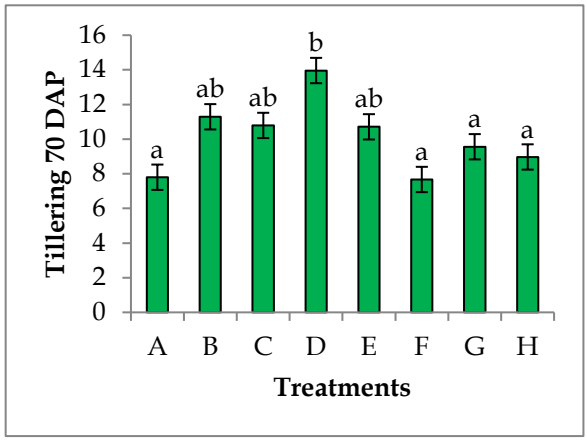

Figure 7 The effect of Biomix-N on paddy plant tillering 70 days after transplanting (DAP).

Based on the Relative Agronomic Effectiveness value (Table 3), the highest percentage of rice plant growth was obtained using 500 kg ha^{-1} Biomix-N fertilization.

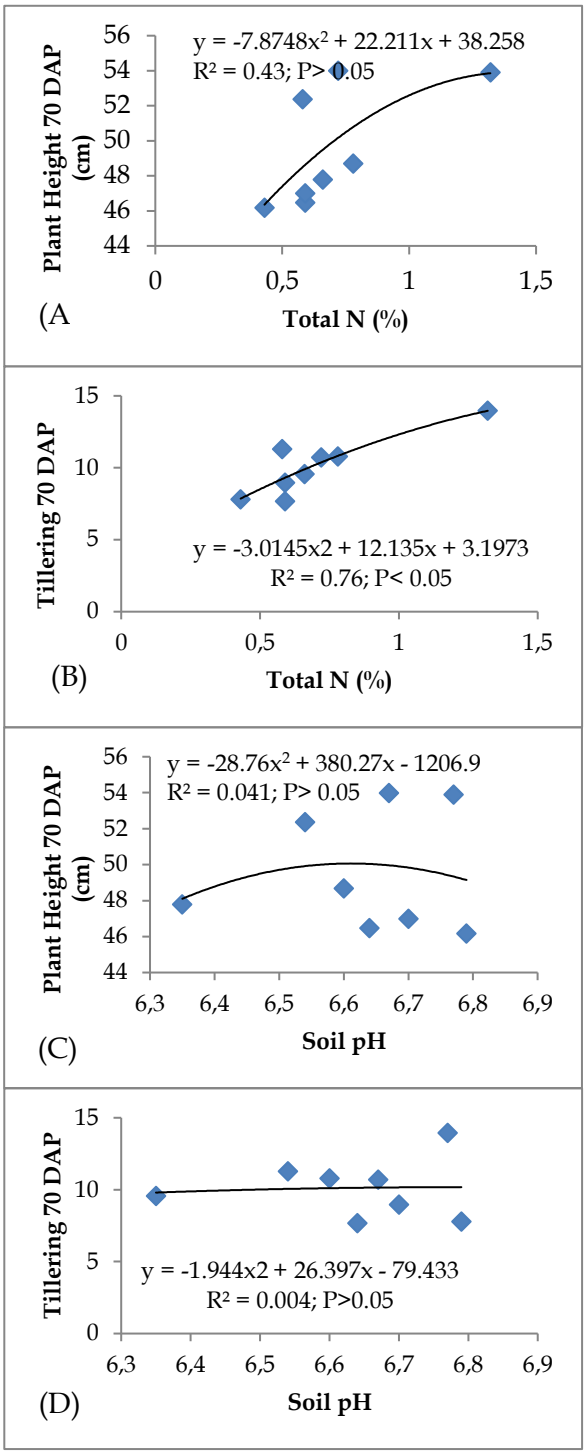

Figure 8 Correlation between total N (A, B) and soil pH (C, D) with plant height and tillering paddy plant.

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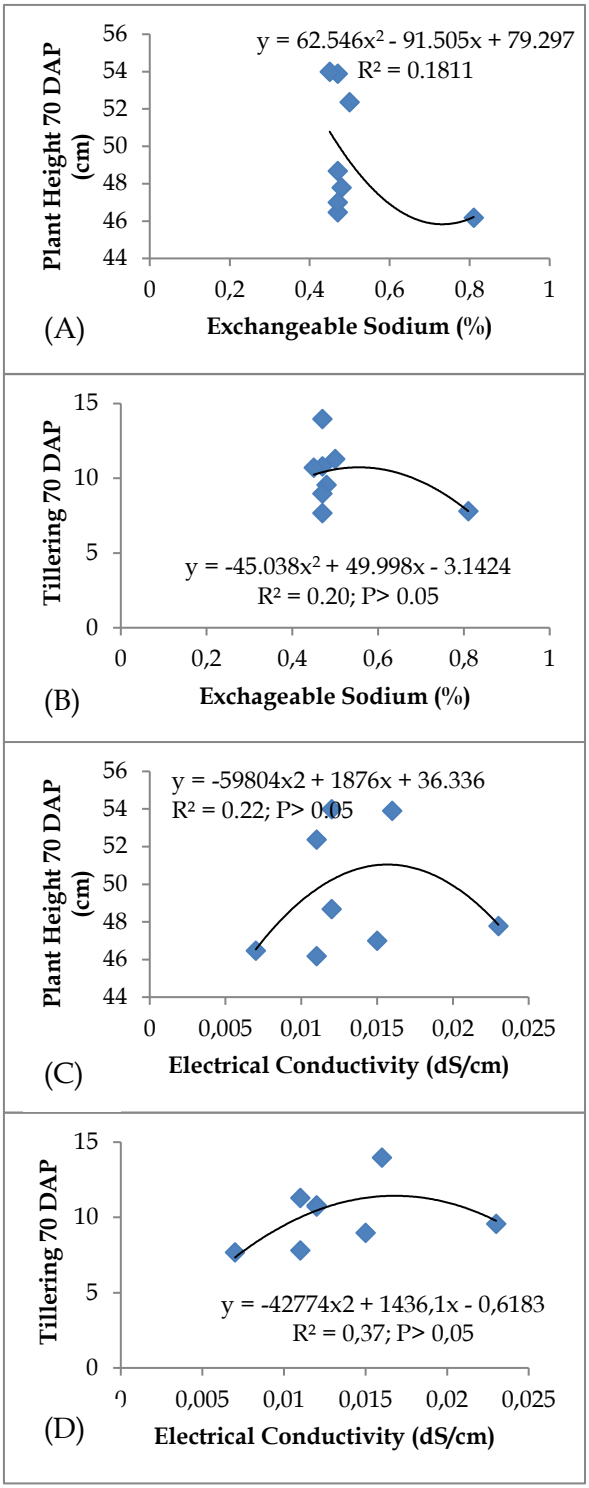

Figure 9. Correlation between Na-ex (A, B) and soil EC (C, D) with plant height and tillering paddy plant.

Table 3. Relative Agronomic Effectiveness (RAE).

	Treatments (kg ha^{-1})	RAE (%)	
		Plant height (cm)	Tillering
A	Control negative	-	-
B	Control positive (Urea)	-	-
C	Biomix-N 250	40.55	85.67
D	Biomix-N 500	124.72‡	176.50‡
E	Biomix-N 750	126.17‡	83.38
F	Biomix-N 1000	4.68	3.72
G	Biomix-N 1250	26.01	50.43
H	Biomix-N 1500	13.25	33.52

Remark: ‡ RAE > 100%

Relationship between Soil Chemical Properties on Plant Height and Number of Tillers. Based on Fig. 8-9 (A, B, C and D), the highest coefficient of determination between Na-ex, N-total, pH and EC with the height and number of tillers of rice plants at 70 days after planting (DAP) was obtained at the N-total, with the plant height (R2 = 0.43) and a number of tillering (R2=0.75). The coefficients of determination for Na-ex, EC and soil pH were relatively small. However, Na-ex exhibited a negative correlation coefficient, indicating that an increase in soil Na-ex can reduce the growth of rice plants (Putra et al., 2021).

Conclusion

Application of Biomix-N 500 kg ha^{-1} affected the soil EC and total N. However, it did not affect exchangeable sodium, Cd soil pH and Cd uptake by paddy plant. The Biomix-N 500 kg ha^{-1} fertilization also influenced the height and the number of tillers of rice plants at the age of 70 DAP. Specifically, the application of Biomix-N fertilization at a rate of 500 kg ha^{-1} resulted in a RAE value ranging from 126-176% compared to the control treatment. The total N content of the soil had a high correlation value (R = 0.9) with the growth of rice plants. Therefore, applying Biomix-N 500 kg ha^{-1} which is equivalent to 300 kg ha^{-1} of urea was an effective dose for paddy soil in the industrial area.

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