Coconut Shell Biochar, Rhizobium and NPK Fertilizer Increased Soil Chemical Properties and NPK Uptake of Edamame in Inceptisol Tempuran, Magelang, Indonesia

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Abstract. This study aims to determine the effect of coconut shell biochar, Rhizobium, and recommended doses of Urea+TSP 36+KCl fertilizer on changes in soil chemical properties and NPK nutrient uptake of edamame plants. Soil sampling was carried out at the beginning before treatment and at harvesting. Sampling of plants was carried out from the age of 7 DAP until the end of the generative phase. This research was conducted in Bolobatur Village, Tempurejo Village, Tempuran District, Magelang Regency, Central Java Province and the Laboratory of the Department of Soil, Faculty of Agriculture, Gadjah Mada University in June 2021–March 2022. The treatment applied was coconut shell biochar with a dose of 0 tons/Ha and 2 tons/Ha, the addition of Rhizobium and without Rhizobium, as well as the addition of 0%, 50%, and 100% recommended doses of Urea+TSP 36+KCl fertilizer. The results showed that the treatment of coconut shell biochar 2 tons/ha, Rhizobium, and 100% recommended dose of Urea+TSP 36+KCl fertilizer had a significant effect on edamame plant height and pod sweetness level. This treatment also has an effect on increasing organic matter, CEC, and the availability of soil NPK. The treatment of coconut shell biochar 2 tons/ha, Rhizobium, and 50% recommended dose of Urea+TSP 36+KCl fertilizer affected N and P uptake so as to reduce N and P fertilization.

Keywords: Coconut shell biochar · edamame plant · NPK uptake · recommended dose of fertilizer · Rhizobium

1 Introduction

Inceptisols are soils that occupy almost 4% of the total tropical area or about 207 million hectares. Inceptisol soils are soils that have a cambic horizon, duripan, with a depth of 100 cm or a fragipan with a depth of 200 cm, and have an ochric epipedon. Inceptisol soil is a developing soil and the effective depth of the soil is shallow so that it requires high nutrient additions. This Inceptisol soil is a young, immature soil due to the rapid formation of parent material. Most of the Inceptisol soils are classified as moderately

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weathered and easily washed out due to the influence of the wet and dry seasons [28]. Therefore, it is necessary to add ameliorant that can help increase the uptake of N, P, and K nutrients and the growth of Edamame plants. The addition of the ameliorant can be done with coconut shell biochar and Rhizobium.

Edamame (*Glycine max* (L.) Merrill.) or also known as vegetable soybean is a type of soybean from Japan which is very well known in Indonesia and has a higher economic value than ordinary soybeans. Edamame has green seeds, soft seed texture, larger seed size, sweeter taste, and less nutty taste than ordinary soybeans. The edamame harvest period is when the legumes are young, green, and the seed filling is almost full (80–90% filling) [8]. The conditions for growing edamame are in tropical and subtropical climates with fairly hot temperatures and relatively high rainfall, so this edamame plant is suitable for planting in Indonesia [10]. The current market opportunity for edamame is quite large, both for export and locally. Edamame productivity can reach 3.5 tons/ha, higher than ordinary soybeans which are only able to produce 1.1–1.5 tons/ha [20]. Increased productivity of edamame can be achieved by innovating cultivation technology in accordance with existing land conditions.

Biochar is a porous solid with a carbon content of 85–95% which is produced by heating at high temperatures from carbon-containing materials. One of the biochars that can be used is biochar from coconut shells. Coconut shell biochar has a pore surface area of 2352.851 m^2/g [1]. The larger pore surface area compared to other materials will affect the amount of space for air, water, and nutrients so that it will be better at retaining water and nutrients. Coconut shell biochar contains 42.01% carbon so it can be used for soil organic matter. Organic C levels in coconut shell biochar are influenced by several environmental factors such as soil pH (H_2O) and climate [20]. The use of organic materials in the form of coconut shell biochar as a soil enhancer that supports plant growth and development is also expected to reduce the use of inorganic fertilizers considering their impact on the environment.

Efforts to reduce inorganic fertilizers in increasing edamame plants can also be done by adding nutrient-fixing bacteria such as *Rhizobium sp.* Edamame plants require essential nutrients, namely N, P, and K. Therefore, a biological N fixing technology is needed through Rhizobium inoculation to efficiently nitrogen fertilization. Rhizobium as a group of bacteria that has the ability to provide nutrients for plants. Rhizobium is a bacterium that is able to fix nitrogen in the air, which when in symbiosis with legume plants, these bacteria will infect plant roots and form root nodules. This rhizobium can only fix atmospheric nitrogen if it is in the root nodules of its legume partners. Utilization of Rhizobium as an inoculant can increase the availability of nitrogen for plants that can support plant productivity. The ability of Rhizobium to fix nitrogen from the air is influenced by the size of the root nodules and the number of root nodules. The bigger or more root nodules are formed, the greater the nitrogen that is tethered [6].

This study aims to determine the effect of addition coconut shell biochar, Rhizobium, and several recommended doses of Urea+TSP 36+KCL fertilizer on changes in soil chemical properties and NPK nutrient uptake in edamame plants. This study provides new insights into the effect of coconut shell biochar and Rhizobium in determining effective fertilizer doses for edamame plants.

2 Methodology

2.1 Research Design and Data Collection

This research was carried out in Bolobatur Village, Tempurejo Village, Tempuran District, Magelang Regency, Central Java Province and Soil Laboratory, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta in June 2021–March 2022. The research phase begins with land preparation with soil management and treatment preparation, which includes 2 tons/ha of coconut shell biochar, 75 kg/ha of rhizobium, recommended dose of fertilizer/ha 100 kg TSP 36, 200 kg urea, and 150 kg KCl. Biochar is made by pyrolysis at a temperature of 500 °C for 2–3 h, then pulverized with a size of 2 mm. Edamame seeds were sown in a plot of 1.2 m × 4 m with a spacing of 20 cm × 20 cm and each hole was given 2 edamame seeds. Planting was carried out using a completely randomized block design (RAKL) with 3 treatments of biochar+Rhizobium+recommended dose of fertilization which was repeated 3 times so that 36 experimental units were obtained. Biochar was applied 7 days before planting and applied to the planting hole, Rhizobium was applied to seeds with coating method before planting, TSP 36 was applied 3 days before planting, and Urea and KCl was applied 10 days and 22 days after planting. Soil sampling was carried out at the beginning before planting and at the end of the vegetative phase which was then prepared to obtain soil with 0.5 mm and 2 mm sieves.

2.2 Analysis of Soil, Tissue, Biochar

Soil analysis was carried out in two different conditions, namely initial soil and treatment soil. The soil parameters observed were moisture content, texture, volume weight, pH H_2O, pH KCl, CEC, organic-C, total-N, P-available, and K-available. Analysis of coconut shell biochar includes parameters of pH H_2O, CEC, total-N, total-P, and total-K. Network analysis was carried out covering the parameters of N-total, P-total, and K-total.

2.3 Data Analysis

The data of all observations were analyzed statistically using analysis of variance (ANOVA) with a significance level of 5% to find out which treatments were significantly different. If the treatments differ significantly (significantly) as indicated by F Count > F Table, = 5%, then the Duncan's multiple distance test (DMRT) is used to find out which treatments are significantly different.

3 Result and Discussion

3.1 Soil Chemical Properties

3.1.1 Soil Texture

The soil texture (Table 1) at the research site is sandy clay loam. Soil dominated by the sand fraction facilitates the penetration of plant roots but the soil becomes easier to pass

Table 1. Initial Soil Characteristics

No	Soil chemical and physical parameter	Value	Unit	Dignity [4]
1.	Texture			Sandy clay loam
	Sand	49	%	
	Silt	27	%	
	Clay	25	%	
2.	Bulk density	1,09	$g{\cdot}cm^{-3}$	–
3.	pH H_2O	6,82	–	Neutral
4.	pH KCl	4,93	–	–
5.	CEC	7,40	$Cmol{\cdot}kg^{-1}$	Low
6.	Soil organic matter	1,34	%	Low
7.	Organic-C	0,01	%	Very low
8.	Total-N	0,22	%	Medium
9.	Available-P	46,29	μg/g	Very high
10.	Available-K	0,43	$Cmol{\cdot}kg^{-1}$	Medium

water so that it has low nutrient availability, on the contrary if the soil is dominated by the clay fraction then the penetration of plant roots is more difficult but the soil is not easy to pass water and nutrients [22].

3.1.2 Bulk Density

Bulk Density (Table 1) in the research area is 1.09 $g{\cdot}cm^{-3}$. The weight of the soil volume is the ratio between the dry weight of the soil and the volume of the soil which includes the volume of the soil pores. The best volume weight is close to the value of 1 $g{\cdot}cm^{-3}$. The volume weight of mineral soils ranges from 0.6 to 1.4 $g{\cdot}cm^{-3}$ [4]. This is influenced by management factors in agricultural land, namely differences in cropping patterns, crop rotation, differences in inundation time, and different land uses [21].

3.1.3 Effect of Treatment Factors on Soil pH

The actual soil pH value is 6.82 which is included in the neutral category while the potential pH value is 4.93 (Table 2). The pH value is influenced by parent material, climate, organic matter, and human activities. The type of soil in this research area has a neutral pH because it is included in the Inceptisol Soil classification. Inceptisol soils have a pH that is acidic to slightly acidic, ranging from 4.6 to 5.5 and acidic to neutral, ranging from 5.6 to 6.8 [3].

At pH H_2O, biochar and fertilization dose had a significant effect, and there was an interaction between the effect of the coconut shell biochar treatment factor, Rhizobium, and the recommended dose of Urea+TSP 36+KCl fertilizer. The increase in pH on the treatment factor occurred because the organic matter had been incubated in the

Table 2. Effect of Treatment Factors on Soil pH

Treatments	pH H_2O		Dignity	pH KCl	
Coconut Shell Biochar					
0 Ton/Ha	6,0	a	Slightly Acid	4,3	b
2 Ton/Ha	6,1	a	Slightly Acid	4,4	a
Rhizobium					
Without *Rhizobium*	6,0	a	Slightly Acid	4,3	a
Rhizobium	6,1	a	Slightly Acid	4,3	a
Fertilizer Remommendation Dose*					
0%	5,8	a	Slightly Acid	4,2	a
50%	6,0	b	Slightly Acid	4,3	b
100%	6,2	c	Slightly Acid	4,4	b
Biochar × *Rhizobium*	(−)			(−)	
Biochar × Dosis	(−)			(−)	
Biochar × *Rhizobium* × Dose	(−)			(+)	

Note: Numbers followed by the same letter in the same column indicate that there is no significant difference at the 5% Duncan test significance level. The sign (+) indicates the presence of interaction and (−) indicates the absence of interaction.
*Urea+TSP 36+KCl Fertilizer

decomposition process, so that it could release organic compounds, both organic acids and base cations, which resulted in an increase in soil pH at higher doses of fertilizer [17].

3.1.4 Effect of Treatment Factors Soil Cation Exchange Capacity

The initial soil CEC content in this study was classified as low (Table 3). Cation Exchange Capacity (CEC) is the ability of the soil to absorb and exchange cations from the soil solution. The CEC value is influenced by the amount and type of clay minerals, organic matter, and soil pH. The low value of the CEC is due to the low clay content. The negatively charged clay fraction can adsorb cations. In addition, the low value of the CEC is caused by a high C/N ratio, which means that the organic matter has not been completely decomposed so that there is no negative charge that is donated to the soil. The negative charge is contributed by organic matter through functional groups, namely hydroxyl and carboxyl [26].

The results showed that the application of biochar can increase the soil CEC. This is because the given organic matter acts as a soil colloid which determines the size of the CEC value. Organic matter is humus which acts as a soil colloid so that when more organic matter is applied, the value of the CEC is also greater. In addition, the increase in CEC by biochar is due to the fact that biochar has a large surface area, surface charge, and charge density so that it is easier to absorb cations [3].

Table 3. Effect of Treatment Factors on CEC

Treatments	CEC ($Cmol{\cdot}kg^{-1}$)		Dignity
Coconut Shell Biochar			
0 Ton/Ha	7,56	a	Low
2 Ton/Ha	8,00	a	Low
Rhizobium			
Without *Rhizobium*	7,92	a	Low
Rhizobium	7,64	a	Low
Fertilizer Remommendation Dose*			
0%	7,37	a	Low
50%	7,85	a	Low
100%	8,12	a	Low
Biochar × *Rhizobium*	(−)		
Biochar × Dosis	(−)		
Biochar × *Rhizobium* × Dose	(−)		

Note: Numbers followed by the same letter in the same column indicate that there is no significant difference at the 5% Duncan test significance level. The sign (+) indicates the presence of interaction and (−) indicates the absence of interaction.
*: Urea+TSP 36+KCl Fertilizer

3.1.5 Effect of Treatment Factors on Soil Organic Matter

The C-organic content of the initial soil was classified as very low (Table 4), while the organic matter content was classified as low. Inceptisol soil is soil that is relatively young and is starting to develop so that soil fertility is low due to soil organic matter content, acidity, and low content of several macro elements. In addition, the low organic matter is caused by high temperatures and fast decomposition rates [5].

In all treatments there was an increase in organic matter levels in the soil before and after treatment. This is because the application of organic matter into the soil can increase the C-organic content in the soil from the reshuffle of organic matter. Low organic matter content also indicates low organic C content. The low value of organic matter is caused by biochar having recalcitrant properties that are resistant to the decomposition process of organic matter so that biochar has not been decomposed further [18].

3.1.6 Effect of Treatment Factors on Total N

The total N content in the initial soil is in the medium class (Table 5). In the soil with the treatment factor, there was an increase in the total N content of the soil. The increase in the total N value was due to coconut shell biochar being very porous so that it became a good place for microbial growth. Surface oxides in biochar are also effective in absorbing NH^{4+} and NO^{3-}, thereby potentially reducing N losses due to leaching [15]. In addition,

Table 4. Effect of Treatment Factors on Soil Organic Matter

Treatments	Soil Organic Matter (%)		Dignity
Coconut Shell Biochar			
0 Ton/Ha	1,91	a	Low
2 Ton/Ha	2,03	a	Medium
Rhizobium			
Without *Rhizobium*	1,92	a	Low
Rhizobium	2,03	a	Medium
Fertilizer Remommendation Dose*			
0%	1,93	a	Low
50%	1,87	a	Low
100%	2,13	a	Medium
Biochar × *Rhizobium*	(−)		
Biochar × Dosis	(−)		
Biochar × *Rhizobium* × Dose	(−)		

Note: Numbers followed by the same letter in the same column indicate that there is no significant difference at the 5% Duncan test significance level. The sign (+) indicates the presence of interaction and (−) indicates the absence of interaction.
*: Urea+TSP 36+KCl Fertilizer

the increase in the value of soil CEC causes N elements to be not easily leached, where in oxidative soils, the N element is dominated by the form of NO^{3-} [26].

3.1.7 Effect of Treatment Factors on Available P

The available P content in the initial soil is classified as very high class (Table 6). In the treated soil, there was an increase in available P levels. Significantly different effect on biochar administration because biochar can increase P reactivity with soil and form insoluble compounds with Ca. Biochar absorbs P element more strongly than other organic materials. The very high available P content was due to the accumulation of inorganic fertilizers such as TSP in previous crop cultivation. P fertilizer given in previous crop cultivation accumulates causing very high available P content [26]. High available P is also closely related to soil pH. The availability of P will be maximum in the pH range between 5,5–7, while at pH 7 the availability of P will decrease [14].

3.1.8 Effect of Treatment Factors on Available K

The available K content in the initial soil is in the medium category (Table 7). In soil with treatment factor, there was not much increase in soil K-available content. The K-available soil content before treatment was 0.43 ppm which was classified as moderate. This happens because the presence of K element is influenced by climate and rainfall,

Table 5. Effect of Treatment Factors on Total N

Treatments	Total-N (%)		Dignity
Coconut Shell Biochar			
0 Ton/Ha	0,21	a	Medium
2 Ton/Ha	0,24	a	Medium
Rhizobium			
Without *Rhizobium*	0,22	a	Medium
Rhizobium	0,23	a	Medium
Fertilizer Remommendation Dose*			
0%	0,21	a	Medium
50%	0,23	a	Medium
100%	0,24	a	Medium
Biochar × *Rhizobium*	(−)		
Biochar × Dosis	(−)		
Biochar × *Rhizobium* × Dose	(−)		

Note: Numbers followed by the same letter in the same column indicate that there is no significant difference at the 5% Duncan test significance level. The sign (+) indicates the presence of interaction and (−) indicates the absence of interaction.
*: Urea+TSP 36+KCl Fertilizer

where K element will be easily lost due to leaching due to high rainfall. The significant difference in the dose of fertilization occurred because of the role of K and P fertilizers.

Fertilizer application affected the exchangeable potassium. K and P fertilizers are used to increase the available K of the soil. Potassium added to the soil through fertilization can saturate the adsorption complex so that an equilibrium is reached with the K of the soil solution. Therefore, K fertilization increases Kdd levels in the soil. P fertilization can also increase the concentration of Kdd because the adsorption of orthophosphate anions increases the negative charge on the soil [16].

3.2 Coconut Shell Biochar Characteristics

The characteristics of coconut shell biochar (Table 8) are in accordance with the minimum technical requirements for soil repair. According to [11], the standard value for soil enhancer for organic C is at least 15% and the pH value is 4–9. Meanwhile, according to [7], the minimum standard value for soil improvement is divided into 3 classes of C-organic. Class 1 has a minimum range value of 60%, class 2 has a minimum range value of 30%, and class 3 has a minimum range value of 10% and <30%. Based on the IBI standardization, the results of the laboratory analysis of C-organic coconut shell biochar fall into class 2. The N-total value of coconut shell biochar is 0.01%, the P-total value is 0.27 ppm, and the total K-value is 0,79 $Cmol \cdot kg^{-1}$. These values are in accordance with the minimum technical requirements for organic soil improver, which is <6%. According to [13], the value of N-total, P-total, and K-total is less than 6%.

Table 6. Effect of Treatment Factors on Available P

Treatments	Available-P (μg/g)		Dignity
Coconut Shell Biochar			
0 Ton/Ha	83,46	b	Very High
2 Ton/Ha	97,87	a	Very High
Rhizobium			
Without *Rhizobium*	86,05	a	Very High
Rhizobium	95,28	a	Very High
Fertilizer Remommendation Dose*			
0%	73,28	b	Very High
50%	98,64	a	Very High
100%	100,08	a	Very High
Biochar × *Rhizobium*	(+)		
Biochar × Dosis	(−)		
Biochar × *Rhizobium* × Dose	(−)		

Note: Numbers followed by the same letter in the same column indicate that there is no significant difference at the 5% Duncan test significance level. The sign (+) indicates the presence of interaction and (−) indicates the absence of interaction.
*: Urea+TSP 36+KCl Fertilizer

The pH value of the biochar material depends on the pyrolysis process and the age of the biochar used. The pH value in the range of 11 occurs when the biochar is still not weathered and the pyrolysis temperature is more than 450–500 °C. If the biochar has undergone a weathering process, the pH range will be 5–8 [23]. The CEC value of coconut shell biochar in this study was 18.22 Cmol·kg^{-1}. The COC value of coconut shell biochar based on the research of [12], ranged from 13.67 to 61.23 Cmol·kg^{-1}. The ash content in coconut shell biochar is 19.29%. According to [25], coconut shell biochar has a low ash content and is resistant to a combustion temperature of 1500 °C.

3.3 Effect of Treatment Factors on Nutrient Levels and Uptake of N, P, K Tissue

3.3.1 Effect of Treatment Factors on Nutrient Levels and Uptake of N

The high uptake area in biochar was able to increase the uptake of nutrients in the roots which were then flowed to the canopy and finally to the pods thereby increasing the N content in the pods and forming assimilate. High N uptake in plants due to the addition of N and Rhizobium fertilizers. Increased N in the tissue will increase the rate of photosynthesis, increase seed productivity, increase seed protein content, and increase the total N content of tissues in the vegetative and generative growth phases obtained from N uptake. Tissue N accumulation is obtained from bacterial fixation which increases N assimilation in plants. Which will increase the N content in leaves, seeds, and plant and

Table 7. Effect of Treatment Factors on Available K

Treatments	Soil-available K ($Cmol{\cdot}kg^{-1}$)		Dignity
Coconut Shell Biochar			
0 Ton/Ha	0,44	a	Medium
2 Ton/Ha	0,45	a	Medium
Rhizobium			
Without *Rhizobium*	0,44	a	Medium
Rhizobium	0,45	a	Medium
Fertilizer Remommendation Dose*			
0%	0,38	c	Low
50%	0,45	b	Medium
100%	0,49	a	Medium
Biochar × *Rhizobium*	(+)		
Biochar × Dosis	(−)		
Biochar × *Rhizobium* × Dose	(−)		

Note: Numbers followed by the same letter in the same column indicate that there is no significant difference at the 5% Duncan test significance level. The sign (+) indicates the presence of interaction and (−) indicates the absence of interaction.
*: Urea+TSP 36+KCl Fertilizer

Table 8. Characteristics of Coconut Shell Biochar

No	Characteristics	Unit	Value
1.	pH H_2O	–	8,948 [11]
2.	CEC	$Cmol{\cdot}kg^{-1}$	18,22
3.	Organic-C	%	46,81 [13]
4.	Kadar Abu	%	19,29
5.	Total-N	%	0,15 [13]
6.	Total-P	ppm	0,27 [13]
7.	Total-K	$Cmol{\cdot}kg^{-1}$	0,79 [13]

seed weight [2]. The recommended dose of 50% fertilizer is the most effective dose in the combination of coconut shell biochar and Rhizobium treatment combinations (Table 9). The use of Rhizobium must be accompanied by a reduction in the amount of N fertilization, this is because Rhizobium does not respond to high N fertilization [27].

Table 9. Effect of Treatment Factors on N Tissue Nutrient Levels and Uptake

Treatments	N concentration (%)						N uptake (mg/plant)					
	root		shoot		pod		root		shoot		pod	
Coconut Shell Biochar												
0 Ton/Ha	2,79	b**	1,04	b**	13,51	b****	29,23	b	49,79	b	234,06	a
2 Ton/Ha	3,56	a**	1,68	a**	14,53	a****	41,30	a	78,62	a	241,32	a
Rhizobium												
Without *Rhizobium*	3,13	a**	1,28	a**	13,95	a****	33,91	a	58,09	a	228,97	a
Rhizobium	3,21	a**	1,43	a**	14,10	a****	36,63	a	70,31	a	246,41	a
Fertilizer remommendation dose*												
0%	2,81	a**	1,17	a**	13,61	a****	30,58	b	53,78	a	204,76	a
50%	3,48	a**	1,59	a**	14,50	a****	39,03	a	81,16	a	256,65	a
100%	3,23	a**	1,32	a**	13,94	a****	36,19	ab	57,67	a	251,67	a
Biochar × *Rhizobium*	(−)		(−)		(−)		(−)		(−)		(−)	
Biochar × Dosis	(−)		(−)		(−)		(−)		(−)		(−)	
Biochar × *Rhizobium* × Dose	(−)		(−)		(−)		(−)		(−)		(−)	

Note: Numbers followed by the same letter in the same column indicate that there is no significant difference at the 5% Duncan test significance level. The sign (+) indicates the presence of interaction and (−) indicates the absence of interaction. *: Urea+TSP 36+KCl Fertilizer Nutrient Sufficiency Range N 4.26–5.50% **: Low ***: adequate ****: High

3.3.2 Effect of Treatment Factors on Nutrient Levels and Uptake of P

The application of biochar can increase the availability of P in the soil. Elemental P is absorbed by the roots and then distributed to the stems and leaves which eventually to the roots. The recommended dose of 50% fertilizer is the most effective dose in the combination of coconut shell biochar and Rhizobium treatment combinations (Table 10). Biochar contains essential nutrients and also the ability to absorb nutrients better. Ion adsorption on biochar charge is also influenced by its functional groups [9]. This functional group in biochar has the ability to adsorb P and donate P [30]. [23] stated that the application of biochar will form a negative charge and increase the CEC. The increase in CEC is due to the formation of carboxylic groups resulting from oxidation on the surface of biochar so that the ability to retain nutrients can be improved. P element also plays a role in the generative process and maximizes the process of formation and filling of pods to seeds. The results of the decomposition of organic matter from biochar produce soil colloids containing positively and negatively charged ions so that they can bind positively charged metal ions in the soil. The binding of metal ions causes element

Table 10. Effect of Treatment Factors on P Tissue Nutrient Levels and Uptake

Treatments	P concentration (%)						P uptake (mg/plant)					
	root		shoot		pod		root		shoot		pod	
Coconut Shell Biochar												
0 Ton/Ha	0,08	b**	0,12	a**	0,76	a****	0,84	b	5,44	b	12,92	a
2 Ton/Ha	0,12	a**	0,16	a**	0,80	a****	1,44	a	7,74	a	13,37	a
Rhizobium												
Without *Rhizobium*	0,11	a**	0,15	a**	0,83	a****	1,19	a	6,81	a	13,68	a
Rhizobium	0,10	a**	0,13	a**	0,72	b****	1,09	a	6,37	a	12,60	a
Fertilizer remommendation dose*												
0%	0,09	a**	0,13	a**	0,77	a****	1,06	a	6,40	a	12,05	a
50%	0,10	a**	0,16	a**	0,79	a****	1,26	a	6,81	a	13,99	a
100%	0,09	a**	0,14	a**	0,78	a****	1,10	a	6,56	a	13,39	a
Biochar × *Rhizobium*	(−)		(−)		(−)		(−)		(−)		(−)	
Biochar × Dosis	(−)		(−)		(−)		(−)		(−)		(−)	
Biochar × *Rhizobium* × Dose	(−)		(−)		(−)		(−)		(−)		(−)	

Note: Numbers followed by the same letter in the same column indicate that there is no significant difference at the 5% Duncan test significance level. The sign (+) indicates the presence of interaction and (−) indicates the absence of interaction. *: Urea+TSP 36+KCl Fertilizer Nutrient Adequacy Range P 0.26–0.50% **: Low ***: Adequate ****: High

P to be more available to plants. The more P elements that are absorbed by plants, the number and the weight of the pods produced also increases.

3.3.3 Effect of Treatment Factors on Nutrient Levels and Uptake of K

The availability of K in the soil is influenced by several factors such as soil pH. Soils with a low pH have the potential to lose K more easily, indicating that they have a low K content. Giving coconut shell biochar treatment factors resulted in an increase in K levels and uptake (Table 11). Biochar has pores that are able to prevent nutrient loss so that roots can absorb nutrients well and then translocate them to stems and leaves. The addition of biochar to increase K uptake is due to the ability of biochar to increase essential nutrients and to increase plant growth and development through improving soil physical and chemical properties [19]. K uptake by plant roots takes place optimally when sufficient ATP energy is available. The highest K uptake occurred in the canopy.

Table 11. Effect of Treatment Factors on K Tissue Nutrient Levels and Uptake

Treatments	K concentration (%)						K uptake (mg/plant)					
	root		shoot		pod		root		shoot		pod	
Biochar												
0 Ton/Ha	0,51	a**	1,14	a**	1,19	a**	5,41	b	56,28	a	20,59	a
2 Ton/Ha	0,60	a**	1,17	a**	1,20	a**	7,08	a	52,21	a	19,91	a
Rhizobium												
Without Rh*izobium*	0,57	a**	1,14	a**	1,12	a**	6,39	a	51,61	a	20,80	a
Rhizobium	0,53	a**	1,18	a**	1,20	a**	6,10	a	56,88	a	19,70	a
Fertilizer remommendation dose*												
0%	0,51	a**	1,10	a**	1,21	a**	5,75	a	49,86	a	21,98	a
50%	0,57	a**	1,20	a**	1,20	a**	6,45	a	57,27	a	20,66	a
100%	0,59	a**	1,16	a**	1,19	a**	6,54	a	55,60	a	18,12	a
Biochar × *Rhizobium*	(−)		(+)		(−)		(−)		(+)		(−)	
Biochar × Dosis	(−)		(−)		(−)		(−)		(−)		(−)	
Biochar × *Rhizobium* × Dose	(−)		(−)		(−)		(−)		(−)		(−)	

Note: Numbers followed by the same letter in the same column indicate that there is no significant difference at the 5% Duncan test significance level. The sign (+) indicates the presence of interaction and (−) indicates the absence of interaction
*: Urea+TSP 36+KCl Fertilizer.
K Nutrient Adequacy Range 1.71–2.50% **: Low ***: Adequate ****: High

Elemental K functions as a transport medium that carries nutrients from roots to leaves and transforms assimilate from leaves to all plant tissues [24].

The addition of biochar as a soil enhancer is able to increase the levels and uptake of K to be more available for plant absorption. This is because biochar contains K nutrients which can improve K nutrient uptake in plants. Potassium contained in biochar can be in the soil solution so that it will be easily absorbed by plants and sensitive to leaching [29].

4 Conclusion

1. The application of biochar, Rhizobium, and recommended doses of fertilizers can change the chemical properties of the soil. There was an increase in the value of soil chemical parameters along with the use of 2 Ton/Ha biochar, the addition of Rhizobium, and the addition of recommended doses of fertilizer.

2. Provision of biochar 2 Ton/Ha, Rhizobium, and 50% recommended dose of fertilizer was more effective in increasing the levels and uptake of N pods, so as to reduce the dose of N fertilizer given. Meanwhile, the application of biochar 2 Ton/Ha and 50% recommended dose of fertilizer was more effective in increasing the levels and uptake of P pods, so as to reduce the dose of P fertilizer given.

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