Ilmu Pertanian (Agricultural Science)
http://journal.ugm.ac.id/jip
Vol. 8 No. 2 August, 2023: 121–132 | DOI: doi.org/10.22146/ipas.83506

Improving basil productivity in coastal sandy soil Yogyakarta by balanced Urea-ZA (N-S) fertilizers and application of soil amendment to increase fertilization effectiveness

Cahyo Wulandari*, Nasih Widya Yuwono, Yudhistira Galang Pravasta, and Sri Lestari

Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada
Jln. Flora no. 1, Bulaksumur, Sleman, Yogyakarta 55281, Indonesia
*Corresponding author: wulan_soil@ugm.ac.id

Article Info

Received : 29th March 2023
Revised : 2nd August 2023
Accepted: 11th August 2023

Keywords:
biochar, nutrient, zeolite

Abstract

Basil is a plant that can be cultivated in Psamment (coastal sandy soil). Basil requires nitrogen (N) and sulfur (S), so the N-S balance is needed to obtain optimal results. Psamment contains low colloid, causing nutrients to be barely bound and easily lost. Zeolite and biochar can be a solution. This study aimed to determine the composition and frequency of fertilization, as well as the use of soil amendment for basil growth. This research consisted of two interrelated studies arranged in a Randomized Complete Block Design. The research was conducted in Bugel, Panjatan, Kulon Progo, and the analysis was performed at the Soil Department Laboratory, Faculty of Agriculture, Universitas Gadjah Mada. The first study consisted of two factors, namely Urea-ZA composition (0:0, 60:40, 70:30, 80:20, 90:10, and 100:0) and frequency of fertilization (every 1 and 2 weeks). The application of Urea-ZA (80:20) gave the best fresh-dry weight, N-S content, and N-S uptake of basil, and this result was used as the reference for the second study. The second study consisted of two factors, namely Urea-ZA fertilizer doses (50%, 75%, and 100%), and types and doses of soil amendment (without amendment, zeolite 7.5 t/ha, zeolite 15 t/ha; biochar 7.5 t/ha, and biochar 15 t/ha). It can be concluded that soil amendments application improved the chemical properties of psamment, fresh-dry weight, N-S content, and N-S uptake of basil. Furthermore, biochar and zeolite could increase the effectiveness of fertilization, so the dose of Urea-ZA fertilizer could be reduced until 50%.

INTRODUCTION

Basil is widely used in medicine, culinary, and perfumery purposes all over the world (Juškevicienˑe et al., 2022). Basil belongs to the Lamiaceae family with leaves containing essential oils (Vilanova et al., 2018). Nitrogen (N) fertilization is needed to increase growth and yield of basil. Nitrogen fertilization has been reported to increase essential oil content in basil (Cirileo et al., 2022). Alhasan et al. (2020) reported that N uptake and biomass production of basil could be improved by the addition of N fertilizer. Besides, nitrogen deficiency causes stunted plant growth related to N assimilation (Larimi et al., 2014). Urea, as the source of nitrogen, becomes the most used fertilizer in the world (Otto et al., 2023) because it contains high N (46% N) of all solid nitrogenous fertilizers (Wang et al., 2020). Urea can be applied alone, or it can be easily mixed with the other fertilizers (Chen et al., 2023). Ammonium sulfate is a nitrogen fertilizer that contains sulfur (21%) (Berhe et al., 2019).

Elwan and Elhamahmy (2015) reported that combination of Urea-ZA fertilizers had a positive interaction effect on plant growth. Urea-ZA fertilizers contain N nutrient needed for plant growth and photosynthesis. Besides, sulfur is an essential

How to cite: Wulandari, C., Yuwono, N.W., Pravasta, Y.G., and Lestari, S. (2023). Improving basil productivity in coastal sandy soil Yogyakarta by balanced Urea-ZA (N-S) fertilizers and application of soil amendment to increase fertilization effectiveness. *Ilmu Pertanian (Agricultural Science)*, 8(2), pp. 121–132.

ISSN 0126-4214 (print) ISSN 2527-7162 (online)

macronutrient. Not only being a part of protein in the methionine and cysteine amino acids component, sulfur can also enhance the production of basil because it has major function in the synthesis of proteins (Ngezimana and Agenbag, 2015). Similar to canola, which produces essential oils, basil yields were maximized with N dan S fertilization (Ngezimana and Agenbag, 2014a). The best N:S ratio that increased nutrient uptake and plant yield was 7:1 (Ngezimana and Agenbag, 2014b). Basil essential oil contains geranial, linalool, methyl eugenol, Z-citrial, 3-methylcyclopent-2-enona, ethyl hexadecanoic acid, ethyl ethyl acid 9-octadechenoic, ethyl octadecanoic acid, and methyl hexadecanoic acid (Jimayu, 2021). The concentration of essential oil showed improvement with the application of S fertilizer (Renata, 2013).

Basil is one of the leading commodities in Psamment (coastal sandy soil) Kulon Progo (Anonim, 2021). The soil type of coastal sandy soil in Yogyakarta is classified into Typic Udipsamment according to soil taxonomy system (Soil Survey Staff, 2014). However, for agricultural production, sandy soils have several of limiting factors. This land is dominated by sand fraction (do not form aggregates) together with low organic matter and CEC, leading to some nutrient easily leached (Minhal et al., 2020). The soil profile can be decreased subsequently because the dissolved nutrients are carried by the percolating water. Some various problems existing in coastal sandy soil need to be solved to increase plant growth. In order to solve these problems, soil amendment is needed. Soil amendment is any material added to the soil to improve its properties, thereby supporting plant growth. A commonly used amendment is zeolite.

A crystalline substance called zeolite has a structure characterized by a framework of connected tetrahedral SiO_4 and AlO_4 that are surrounded by oxygen anions (O_2^-). The porous structure of zeolite, which has many channels and cages as open cavities, enables ions pass through the channel pores (Moshoeshoe et al., 2017). This internal surface area makes zeolite a very effective ion exchanger (Sangeetha and Baskar, 2016). Zeolite can be used as a material that supports fertilizer to be released slowly (slow release) by utilizing its surface area and adsorption capacity (Anwar et al., 2022). Zeolite deposits are a non-renewable resource (Krol, 2020), so that it can run out over time. Therefore, materials that have the same capabilities as zeolite but renewable and more abundant are needed, one of which is biochar.

Biochar is a material with a high content of carbon and produced from forestry and agricultural biomass residues (Shareef and Zhao, 2016). Biochar can bind cations such as NH_4^+, K^+, Ca^{2+}, and Mg^{2+} due to its abundance of negative functional groups on the surface (Hue, 2020). Biochar addition to the soil can enhance the plant growth and yield because it can increase nutrient retention, improve habitat for microorganisms, improve soil structure, and increase nutrient absorption by plants (Rawat et al., 2019). The combination of biochar and inorganic fertilizers can increase the availability of nutrients in various types of soil. Biochar reduces nutrient leaching in soil and also increases nutrient availability for plants (Nurjanah et al., 2022). Biochar is a recalcitrant carbon and hard to be degraded (Pariyar et al., 2020).

The effectiveness of fertilization is still considered necessary because fertilizers have an important role in increasing basil yield. Understanding fertilizer composition, fertilization frequency, and soil amendment is very important to produce high basil yields, especially in coastal sandy soil. The results of this study help develop strategies for basil farming in coastal sandy soil.

MATERIALS AND METHODS

This study was conducted from May to August 2022, in the coastal sandy soil experimental fields of Bugel, Panjatan District, Kulon Progo Regency, Yogyakarta. Plant and soil analyses were carried out in the laboratories of Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada. This study consisted of two parts. The first one was arranged in a completely randomized block design consisting of two factors. The first factor was Urea-ZA fertilizer composition, including N0 (Urea 0%+ ZA 0%), N1 (Urea 60%+ ZA 40%), N2 (Urea 70%+ ZA 30%), N3 (Urea 80%+ ZA 20%), N4 (Urea 90%+ ZA 10%), and N5 (Urea 100%+ ZA 0%) from the recommendation of 112.5 kg N/ha. The second factor was frequency of fertilization, which were every 1 week and every 2 weeks. Each treatment consisted of 3 replications, resulting in the total of 36 plots.

The plots dimension was 1.54 m² with plant spacing of 30 x 30 cm in each plot. Basil seedlings were transplanted at the age of 3 weeks after sowing. Two tons of quail manure was used as a basic fertilizer applied before planting by scattering appropriate amounts evenly over the soil surface. SP-36 (100 kg/ha) and KCl fertilizer (100 kg/ha) was given 7 days after planting (1 week after planting). Soil samples and plant tissues were collected from each plot at harvest (42 days after planting).

From the first study, the best treatment result was selected to be used as a reference for treatment in the second study. The second study was arranged in a Randomized Complete Block Design (RCBD) consisting of two factors, and each treatment consisted of three replications, resulting in total of 45 plots. The first factor was the dose of Urea-ZA fertilizer (50%, 75%, and 100% from the recommendation of 112.5 kg N/ha), and the second factor was the dose and type of soil amendment with 5 kinds of treatment (without soil amendment, zeolite (7.5 t/ha), zeolite (15 t/ha), biochar (7.5 t/ha) and biochar (15 t/ha)). Before application, 1/3 of Urea-ZA fertilizer was mixed with 1/3 of the soil amendment according to the treatment dose. The ratio of Urea-ZA fertilizer used was 80%:20% (referring to the first study). The application of Urea-ZA fertilizer mixed soil amendment was carried out in 2 ways, namely ring placement (1 weeks after planting (WAP)) and placed between 4 plants (3 and 5 WAP). The mixture of Urea-ZA fertilizer and soil amendment was applied once every 2 weeks. Application was divided into 3 stages (1/3 of the full dose for each fertilization stage).

Field measurements of permeability were performed using the minidisk infiltrometer. Plant growth parameters resulted from measurements of the three best plant samples in each plot. The observed variables were fresh and dry matter weight of root-shoot, content and uptake of N root-shoot, and content and uptake of S root-shoot. The fresh weight of plant root-shoot was measured by weighing all fresh matter. The dry weight of plant tissue was measured by weighing the plant of each treatment after being dried at 80°C to oven dry. The N content of plant tissue was measured using the Kjeldahl method, while S was measured using the wet destruction method ($HClO_4$ 70% and HNO_3 65%).

The soil samples were air-dried before measurement. The soil was initially examined for pH, electrical conductivity (EC), organic C using the Walkey and Black method, CEC using an ammonium acetate solution at pH 7, total N using the Kjeldahl method, and total S using wet destruction method using $HClO_4$ 70% and HNO_3 65%. The results were analyzed using ANOVA at a confidence level of 95%, and differences between treatments were tested using the Duncan Multiple Range Test (DMRT) at a confidence level of 95%.

RESULTS AND DISCUSSION

Initial soil properties before treatment

Based on Table 1, the initial soil texture (before treatment) consisted of 92.84% sand, 4.03% silt, and 2.36% clay. According to the USDA texture triangle, this soil is categorized as sand. It appears that the coastal sandy soil in the field is classified as rapidly permeable, indicating domination of macropores that facilitate nutrients rapidly leach to the groundwater.

The studied coastal sandy soil is sodic (Balittanah, 2009) with the pH value of 6.92. This value is in the optimal pH range for plant growth (5.5–7.5) (Oshunsanya,

Table 1. Characteristics of coastal sandy soil in Bugel, Kulon Progo

No	Parameter	Value	Unit	Level
1.	Texture			
	Sand	92.84	%	Sand
	Silt	4.03	%	Sand
	Clay	2.36	%	Sand
2.	pH H_2O	6.92	-	Neutral*
3.	pH KCl	6.28	-	-
4.	EC	0.12	dS/m	Very low
5.	CEC	5.01	cmol/kg	Very low
6.	Organic C	0.01	%	Very low
7.	Organic matter	0.02	%	Very low
8.	Total N	0.04	%	Very low
9.	Total S	0.008	%	Very low
10.	Permeability	15.00	cm/h	Rapid

Remarks: Categories based on Balai Penelitian Tanah (2009).

2019). Meanwhile, the electrical conductivity in this study was 0.12 dS/m. Tan (1982) reported that low EC (<0.75 mmho/cm) was optimal for plant growth. Psamment Bugel used for research does not have salinity problems even though it is located near the beach. This is because the area used for research does not suffer seawater intrusion, so the surrounding water and soil tend to be fresh and contain little salt.

The studied soil has low ability to exchange cations with the CEC value of 5.2 cmol/kg due to the predominance of sand fractions and low colloidal content of the soil. The type, amount of clay minerals, and the content of organic matter influence the CEC value (Havlin et al., 2019). The studied soil has very low organic C content (0.01%) with the organic matter value of 0.02%. Decomposition of organic matter increases in the temperature range of 20 to 40°C (Havlin et al., 2019). Therefore, the improvement of sandy land with the use of organic matter should be given in large quantities.

The studied coastal sandy soil has low organic matter with the total nitrogen content of 0.04%. Dhillon et al. (2018) mention that the quantity and quality of organic matter affects the nitrogen content in the soil. The domination of sand fraction in the texture of the coastal sandy soil causes nutrients not to be bound to soil particles and is easily carried away by gravitational water outside the root zone. This nitrogen loss ultimately decreases the total N soil content (Budiyanto, 2016). The initial total S content of coastal sandy soil was 0.008%, which is classified as very low. Coastal sandy soil with a predominance of sand fractions causes inorganic S not to be bound to soil particles, so that they are easily lost to the movement of water (Zenda et al., 2021).

Rice husk biochar

The data of rice husk biochar characteristics are presented in Table 2. The biochar used in this study was made using a simple pyrolysis method. Rice husk biochar has an alkaline pH value. Based on the analysis results, the organic C content in biochar was 33.14%. Biochar cannot provide nutrients directly to plants because the nutrient content is low (Nurjanah et al., 2022). Rice husks biochar contained total N and total S of 0.28% and 0.27%. The low total N content in biochar was influenced by the pyrolysis process, causing N nutrients to be lost due to volatilization (Aslam et al., 2021).

The studied biochar had good cation exchange ability with a CEC value of 17.51 cmol/kg. The CEC of biochar is influenced by pyrolysis temperature. The application of biochar can increase the CEC of soil and affect the nutrient retention (Aslam et al., 2021). The rice husk biochar has a lot of amorphous silica (Prangkongkep et al. 2020) with the ash content of 42.77%. Ash in biochar also contains nutrients such as Ca, Mg, Zn, Mn, and P (Aslam et al., 2021).

Zeolite

The studied natural zeolite was clinoptilolite from West Java. Zeolites were activated by heating at 250°C

Table 2. Biochar characteristics

No	Chemical Properties	Unit	Value
1.	pH H_2O	–	8.2
2.	CEC	$cmol.kg^{-1}$	17.51
3.	Organic C	%	33.14
4.	Organic matter	%	57.14
5.	Total N	%	0.28
6.	Total S	%	0.27
7.	Ash	%	42.77

Table 3. Zeolite characteristics

No	Parameters	Unit	Value
1.	pH H_2O	–	7.94
2.	CEC	$cmol.kg^{-1}$	100.20
3.	Water content	%	3.47
4.	Size	%	80.1 (particles escaped 60 mesh)

Table 4. Quail manure characteristics

No	Parameters	Unit	Value
1.	pH H_2O	–	7.12
2.	CEC	cmol.kg^{-1}	20.34
3.	Organic C	%	7.8
4.	Total N	%	1.95

Table 5. Effects of the composition and frequency of Urea-ZA fertilizer application on the growth of basil at Bugel coastal sandy soil, Kulon Progo (42 DAP)

Treatment	Shoot Fresh Weight (g)	Shoot Dry Weight (g)	Root Fresh Weight (g)	Root Dry Weight (g)
Fertilization Frequency				
1 Week	226.42 a	35.37 a	21.48 a	5.92 a
2 Week	187.28 b	33.27 b	19.45 a	5.60 a
Fertilizer Composition				
Urea 0%+ ZA 0%	196.50 b	32.07 bc	18.16 a	5.22 a
Urea 60%+ ZA 40%	180.13 b	23.15 c	19.18 a	5.13 a
Urea 70%+ ZA 30%	215.15 ab	33.39 bc	22.13 a	6.27 a
Urea 80%+ ZA 20%	242.29 a	47.385 a	23.69 a	6.51 a
Urea 90%+ ZA 10%	190.48 b	31.08 bc	18.73 a	5.45 a
Urea 100%+ ZA 0%	216.56 ab	38.84 ab	20.91 a	6.00 a
Interaction	(+)	(+)	(–)	(–)

Remarks: Means followed by the same letters in the same column indicate no significant difference between treatments at a significance level of α=5%.

to affect the loss of the hydration water. Activation through heating will improve its adsorption ability (Widhiyanuriyawan and Hamidi, 2013). Based on the results of zeolite analysis in Table 3, zeolite has an alkaline pH and high CEC (100.20 cmol/kg). High CEC of zeolite can increase fertilization efficiency and increase crop yields. Zeolite used in this study has a particle size of 60 mesh with a moisture content of 3.47%.

Quail manure

The manure used in this study was quail manure. Quail manure has an alkaline pH value. The maturity level of manure is classified as mature with C/N ratio of 4. The results of the decomposition of manure will release nutrients. The total N content of manure was 1.95% (Table 4). Quail manure is a source of organic colloids. The ability of the studied manure to exchange cations (CEC) was 20.34 cmol/kg.

Plant growth (first study)

The result (Table 5) showed that the combination between Urea-ZA fertilizer significantly affected the fresh and dry weight of roots and shoots of basil. On the other hand, fertilization without a combination of urea-ZA gave lower yields. This can be caused by the interaction between Urea-ZA. Composition of Urea fertilizer 80% + ZA 20% and the frequency of fertilization every one week gave the highest effect on the fresh and dry weight of roots-shoots (Table 5). The growth of basil plants can be increased by providing fertilizers that have the perfect balance of Nitrogen and Sulphur (N:S) (Oliveira et al., 2014). Zenda et al. (2021) mentioned that the optimum ratio of nitrogen and sulfur in the soil was 7:1. On the other hand, the most optimal N:S ratio for essential oil-producing plants was 4:1 to 8:1 (Teuber et al., 2020). Nitrogen fertilizer plays an important role in plant growth, development, and yield (Acharya et al., 2020). Sulfur has an important role, especially in plants that produce essential oils, including the formation of the amino acid methionine and cysteine, with 21% and 27% S content (Kumar et al., 2021). Nitrogen and Sulfur nutrients have interactions that will affect plant growth. Sulfur deficiency has an impact on the efficiency of nitrogen. N deficiency has an impact on the efficiency of sulfur, especially in essential oil-producing plants (Kolega et al., 2020).

Table 6. Effects of the composition and frequency of Urea-ZA fertilizer application on the nutrient uptake of basil at Bugel coastal sandy soil, Kulon Progo (42 DAP)

Treatment	Total N Shoot (%)	Total N Root (%)	Total S Shoot (%)	Shoot N Uptake (g/plant)	Root N Uptake (g/plant)	Shoot S Uptake (g/plant)
Fertilization Frequency						
1 Week	8.49 a	5.18 a	0.15 a	2.88 a	0.30 a	5.08 a
2 Week	7.62 a	5.96 a	0.11 a	2.68 a	0.34 a	3.77 b
Fertilizer Composition						
Urea 0%+ ZA 0%	5.60 b	5.00 a	0.09 bc	1.75 b	0.24 b	2.92 b
Urea 60%+ ZA 40%	8.02 ab	5.00 a	0.12 abc	1.75 b	0.24 b	3.09 b
Urea 70%+ ZA 30%	8.68 a	5.47 a	0.14 ab	3.05 ab	0.34 b	4.83 b
Urea 80%+ ZA 20%	9.20 a	7.84 a	0.17 a	4.33 a	0.50 a	7.60 a
Urea 90%+ ZA 10%	8.52 a	4.89 a	0.16 a	2.74 ab	0.28 b	5.11 b
Urea 100%+ ZA 0%	8.18 a	5.20 a	0.07 c	3.06 ab	0.31 b	2.99 b
Interaction	(−)	(−)	(−)	(−)	(−)	(+)

Remarks: Means followed by the same letters in the same column indicate no significant difference between treatments at a significance level of α=5%.

Concentration and nutrient uptake (first study)

The result (Table 6) showed that the combination between Urea-ZA fertilizer significantly affected the N root and shoot uptake. Fertilizer composition of Urea 80% + ZA 20% and the frequency of fertilization every one week gave the highest effect on the N root and shoot uptake. Composition of Urea fertilizer 80% + ZA 20% and the frequency of fertilization every one week gave the highest effect on the S root and shoot uptake. Colleagues et al. (2020) stated that the best N:S ratio for essential oil-producing plants such as canola and basil was between 4:1 to 7:1. Plants are able to absorb more nutrients from the soil in the generative phase than during the vegetative phase, so fertilization with short intervals is more effective (FAO, 1984).

The results obtained showed an increase in plant biomass, N uptake, and S uptake in fertilizer treatments that had a combination of N-S. Fertilizer treatments without S content showed lower results. Nitrogen and sulfur nutrients are known to have interactive effects on plant growth and development. Nitrogen fertilization can increase plant biomass (Acharya et al., 2020). In basil, S nutrient can increase the fertilization and result in higher biomass accumulation and eucalyptol concentrations in the leaves (Kolega et al., 2020). The ratio of N and S available in the soil has an impact on the efficiency of their utilization in plants (Kumar et al., 2021). Nitrogen and sulfur requirements in plants are closely related because these two nutrients are needed for amino acids containing cysteine and methionine, protein synthesis, and various other cellular components (Teuber et al., 2020). The addition of S is necessary for the efficiency of N utilization by plants. But on the other hand, too much addition of N to the soil will cause S deficiency (Kumar et al., 2021). Sulfur deficiency in soil will reduce the ability of plants to absorb N, which will affect the reduction of plant biomass and quality (Walia and Kumar, 2021).

Soil chemical properties (second study)

The results showed that the addition of Urea-ZA fertilizer significantly affected pH and EC. The results of soil analysis after the field experiments showed that the addition of Urea-ZA fertilizer decreased pH. However, neither type and dose of soil amendment, nor the interaction between Urea-ZA and soil amendment type had no significant effect on soil pH. Nitrogen transformation from application of Urea-ZA (such as nitrification) that produces H^+ ions into the soil contribute to soil acidification. ZA releases more H^+ ions than Urea, thereby having a greater effect on lowering the pH in the soil (Havin et al., 2019). Decreasing the pH does not have a major impact on plant growth because the average pH is still at a neutral level (5.99–6.12). The increase in EC occurred when the dose of Urea-ZA fertilizer was increased due to the input of nutrients and salt into the soil (Carmo et al., 2016).

The addition of soil amendment both zeolite and biochar did have significant effect on CEC. There was no significant difference between zeolite and biochar

Table 7. Effects of doses of Urea-ZA fertilizer combined with doses and types of soil amendment on soil properties in Bugel coastal sandy soil, Kulon Progo (42 DAP)

Treatment	pH H_2O	EC (dS/m)	CEC (cmol/kg)	Organik C (%)	N- total (%)
Dosage Urea-ZA					
50%	6.54 a	0.21 b	6.86 a	0.016 a	0.27 a
75%	6.45 a	0.26 ab	7.06 a	0.016 a	0.23 a
100%	6.32 b	0.31 a	7.05 a	0.016 a	0.25 a
Soil amendment					
Without amendment	6.47 a	0.12 a	5.65 c	0.015 c	0.10 c
Zeolite 7.5 t/ha	6.52 a	0.15 a	6.89 b	0.016 bc	0.19 b
Zeolite 15 t/ha	6.48 a	0.15 a	7.27 ab	0.014 c	0.30 ab
Biochar 7.5 t/ha	6.40 a	0.16 a	7.48 ab	0.017 ab	0.26 ab
Biochar 15 t/ha	6.45 a	0.19 a	7.66 a	0.180 a	0.39 a
Interaction	–	–	–	–	–

Remarks: Means followed by the same letters in the same column indicate no significant difference between treatments at a significance level of α=5%. Dosage Urea-ZA 100% = 112.5 kg N/ha.

doses of 7.5 and 15 t/ha. Biochar and zeolite treatments did not have a significantly different effect on soil CEC. Biochar has a high surface area and porosity with various functional groups that are able to adsorb ions (Kavitha et al., 2018). Zeolite is a crystalline, hydrated aluminosilicate (Doni et al., 2020) having an open structure and pore channels that result in a high specific surface area for nutrient storage and exchange (Aslani et al., 2021). Thus, both types of soil amendment could contribute to the increase in the soil CEC.

According to Table 7, the addition of biochar significantly affected the percentage of soil organic carbon. There was no significant difference in the application of 7.5 to/ha and 15 ton/ha biochar. The addition of 15/ha of biochar produced the highest organic carbon (0.18%), while the treatment without soil amendment and zeolite did not show a significant effect on organic C. This is because biochar is recalcitrant (stable) carbon in the soil (Abrishamkesh et al., 2015). Making biochar at high temperatures causes biochar to lose functional groups and aromatic ring complexes that are resistant to biotic and abiotic degradation (Zimmerman and Gao, 2013).

Zeolite and biochar significantly affected the remaining total N content of soil. Binding of NH_4^+ on the negative surface of zeolite and biochar, which is released slowly according to plant needs can suppress the nitrification and nitrogen leaching processes. Thus, the loss of N in the soil can be reduced (Budiyanto, 2020; Li et al., 2021). This result is possible due to the influence of mixing zeolite or biochar with Urea-ZA fertilizer.

Plant growth (second study)

The results (Table 8) showed that the addition of biochar and zeolite significantly affected the fresh and dry weight of roots and shoots of basil. The highest increase in the fresh and dry weight of roots and shoots was found in the treatment of biochar 15 ton/ha, which increased the yield by 100% compared to without soil amendment. The dose of Urea-ZA fertilizer did not affect the fresh and dry weight of roots-shoots. The addition of 50% Urea-ZA fertilizer showed an effect on plant growth that was not significantly different from the addition of 75% and 100%. Urea-ZA fertilizer at a dose of 75% showed the highest yield on all plant growth parameters.

Fresh and dry weight was increased by the application of Urea-ZA combined with soil amendment. The increase in fresh and dry weight of basil with the addition of biochar and zeolite was due to the ability of biochar and zeolite to affect the release rate of N from Urea-ZA fertilizer into the soil. Nitrogen nutrient from Urea-ZA fertilizer would be released slowly (Souri et al., 2019). This relates to the function of nitrogen in plants. Increasing the availability of N in the soil causes an increase in the rate of photosynthesis, transpiration, and stomatal conductance (Sampaio et al., 2021), thereby increasing the yield of basil.

Biochar and zeolite had a significant effect on the volume of basil roots. Root volume in the treatment with soil amendment produced significantly different values with an increase of 100% when compared to the treatment without soil amendment. Zeolite and

Table 8. Effects of doses of Urea-ZA fertilizer combined with doses and types of soil amendment on the agronomic parameters of basil in Bugel coastal sandy soil, Kulon Progo (42 DAP)

Treatment	Root fresh weight (g)	Root dry weight (g)	Shoot fresh weight (g)	Shoot dry weight (g)	Root volume (cm³)
Dosage Urea-ZA					
50%	19.59 a	4.79 a	165.10 a	24.64 a	6.16 a
75%	21.12 a	5.55 a	190.17 a	28.59 a	7.07 a
100%	20.01 a	5.00 a	182.03 a	27.19 a	6.55 a
Soil amendment					
Without amendment	13.86 b	3.11 b	117.68 b	15.71 b	4.06 b
Zeolite 7.5 t/ha	20.30 a	5.31 a	180.21 a	26.95 a	6.93 a
Zeolite 15 t/ha	21.26 a	5.54 a	200.06 a	30.12 a	6.96 a
Biochar 7.5 t/ha	21.57 a	5.59 a	200.89 a	30.26 a	7.07 a
Biochar 15 t/ha	24.20 a	6.03 a	204.60 a	31.00 a	8.20 a
Interaction	–	–	–	–	–

Remarks: Means followed by the same letters in the same column indicate no significant difference between treatments at a significance level of α=5%. Dosage Urea-ZA 100% = 112.5 kg N/ha.

Table 9. Effects of doses of Urea-ZA fertilizer combined with doses and types of soil amendment on the nutrient content and uptake of basil in Bugel coastal sandy soil, Kulon Progo (42 DAP)

Treatment	Total N root (%)	Total N shoot (%)	Total S root (%)	Root N uptake (g/plant)	Shoot N uptake (g/plant)
Dosage Urea-ZA					
50%	2.93 a	6.25 a	0.18 a	0.14 b	1.42 b
75%	2.88 a	6.11 a	0.17 a	0.16 a	1.77 a
100%	2.89 a	6.08 a	0.18 a	0.15 b	1.71 ab
Soil amendment					
Without amendment	2.73 a	5.32 b	0.15 b	0.09 b	0.84 b
Zeolite 7.5 t/ha	2.80 a	6.01 b	0.18 a	0.16 a	1.69 a
Zeolite 15 t/ha	2.95 a	6.79 a	0.18 a	0.17 a	1.95 a
Biochar 7.5 t/ha	3.08 a	6.29 ab	0.20 a	0.17 a	1.82 a
Biochar 15 t/ha	2.93 a	6.33 ab	0.18 a	0.18 a	1.89 a
Interaction	–	–	–	–	–

Remarks: Means followed by the same letters in the same column indicate no significant difference between treatments at a significance level of α=5%. Dosage Urea-ZA 100% = 112.5 kg N/ha.

biochar increase plant root volume by increasing nutrient retention and preventing nutrient loss through leaching. Besides being able to suppress nutrient loss, it can also increase water retention. This condition support the development of roots and plant growth. It was supported by the availability of the percentage of water and nutrients in the soil pores as well as by increasing soil aggregation. Zeolite and biochar improve soil structure so that it can increase the water available to plants (Ghorbani et al., 2022).

Concentration and nutrient uptake (second study)

According to Table 9, zeolite and biochar significantly affected root and shoot uptake of basil. The application of soil amendments increased the total N uptake of roots with the highest yield observed in the treatment of 15 t/ha biochar. The addition of soil amendments increased the total N uptake of shoots by 100% when compared to without amendments. The addition of 15 t/ha zeolite gave the highest yield in shoot uptake (1.95 gram/plant), while the lowest value was in the treatment without fertilizer (0.84 gram/plant). There was no significant difference effect between the applications of 7.5 t/ha and 15 t/ha of zeolite or biochar on total N uptake of roots and shoots.

Small pores in biochar are a good habitat for microorganisms. The activity of soil microorganisms encourages more nutrients to be available so that nutrients can be absorbed by plants properly (Lusmaniar et al., 2022). The addition of other soil amendment generally increases soil microbial biomass. Increasing microbial biomass increases N immobilization and reduces N leaching (Karhu et al., 2021). Zeolite mixed with Urea fertilizer binds ammonium ions released by Urea fertilizer during hydrolysis. Thus, the availability of N nutrients increases so that it can be absorbed by plants (Suwardi, 2009).

The addition of zeolite and biochar had a significant effect on the content and total S absorption of basil shoots when compared to no soil amendment (Table 9). The addition of biochar and zeolite showed results that were not significantly different. Increasing the dose of fertilizer had no significant effect on the level and total S uptake of shoots. The S element in the soil can be absorbed by plants because SO_4^{2-} can dissolve in the soil solution so that plant roots are able to absorb the S element (Narayan et al., 2022). SO_4^{2-} in soil solution is mobile so that it is easily lost (Edwards, 1998). Zeolite and biochar are able to reduce nutrient losses (Gholamhoseini and Bagheri, 2018; Nyambo et al., 2018) so that it can increase nutrient uptake.

CONCLUSIONS

The results of the first study showed that the application of Urea:ZA (80%:20%) gave the best results in shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, shoot and root N content, shoot and root N uptake, and S uptake of basil. The results of the second study proved that Urea-ZA fertilizers rate could be reduced to 50% of recommendation rate in basil with application of soil amendment, resulting similar productivity to the application of 75% and 100% Urea-ZA fertilizer rate. Biochar showed similar results as a soil amendment compared to zeolite. This research will be useful for farmers and other researchers to increase the productivity of basil, especially for further research on essential oils.

ACKNOWLEDGMENTS

Authors are highly grateful to the Faculty of Agriculture, Universitas Gadjah Mada for providing facilities.

REFERENCES

Abrishamkesh, S., Gorji, M., Asadi, H., Bagheri-Marandi, G. H., and Pourbabaee AA. (2015). Efects of Rice Husk Biochar Application on the Properties of Alkaline Soil and Lentil Growth. *Plant Soil Environ*, 61(11), pp. 475–482.

Acharya, T. P., Reiter, M. S., Welabum, G., and Arancibia, R. A. (2020). Nitrogen Uptake and Use Efficiency in Sweet Basil Production Under Low Tunnels. *HortScience*, 55, pp. 429–435.

Aslam, M. A., Aziz, I., Shah, S. H., Muhammad, S., Latif, M., and Khalid, A. (2021). Effects of Biochar and Zeolite Integrated with Nitrogen on Soil Characteristics, Yield and Quality Of Maize (*Zea Mays* L.). *Pak. J. Bot.*, 53(6), pp. 2047–2057.

Aslani, P., Davari, M., Mahmoodi, M. A., Hosseinpanahi, F., and Khaleghpanah, N. (2021). Effect of Zeolite and Nitrogen on Some Basic Soil Properties and Wheat Yield in Potato-Wheat Rotation. *Agricultural Engineering - Scientific Journal of Agriculture*, 44 (1), pp. 97–119.

Berhe, G., Abraha, H., and Haftu, W. (2019). Evaluation of Urea and Ammonium Sulfate on Yield and Yield Components of Sesame (*Sesamum indicum* L.) Under High pH Vertisol of Western Tigray, Northern Ethiopia. *Cogent Food and Agriculture*, 5, pp. 1–11.

Budiyanto, G. 2016. Pengendalian Pencucian Senyawa Nitrat Guna Meningkatkan Produktivitas Lahan Marginal Pantai Kulon Progo DIY. *Planta Tropika: Journal of Agro Science*, 4(1), pp. 46–57.

Carmo, D. L. D., Lima, L. B. D., and Silva, C. A. (2016). Soil Fertility and Electrical Conductivity Affected by Organic Waste Rates and Nutrient Inputs. *Revista Brasileira De Ciência Do Solo*, 40.

Chen, F., Miao, C., Duan, Q., Jiang, S., Liu, H., Ma, L., Li, Z., Bao, X., Lan, B., Chen, L., and Yu, L. (2023). Developing Slow Release Fertilizer Through In-Situ Radiation-Synthesis of Urea-Embedded Starch-Based Hydrogels. *Industrial Crops and Products*, 191, pp. 1–11.

Cirileo, M., Kyriacou, M. C., Pascale, S. D., and Rouphael, Y. (2022). An Appraisal of Critical Factors Configuring the Composition of Basil in Minerals, Bioactive Secondary Metabolites, Micronutrients and Volatile Aromatic Compounds. *Journal of Food Composition and Analysis*, 111, pp. 1–11.

Dhillon, J., Del Corso, M. R., Figueiredo, B., Nambi, E., and Raun, W. 2018. Soil Organic Carbon, Total Nitrogen, and Soil pH, in a Long-Term Continuous Winter Wheat (*Triticum aestivum* L.) Experiment. *Communications in Soil Science and Plant Analysis*, pp. 1–12.

Doni, S., Gisperti, M., Perruzi, E., Macci, C., Matti, G. B., Manzi, D., Masini, C. M., and Grazia, M. (2020). Impact of Natural Zeolite on Chemical and Biochemical Properties of Vineyard Soils. Soil Use and Management., 37(4),pp. 832–842.

Edwards, P. J. (1998). Sulfur Cycling, Retention, and Mobility in Soils: A Review. *USDA Forest Service, Delaware*, pp. 1–2.

Elwan, M. and Elhamahmy, M. (2015). Reduction of Nitrate Content in Response to Salicylic Acid in Spinach and Parsley Fertilized with Two Different N-Sources. *Hortscience Journal of Suez Canal University*, 3(1), pp. 15–23.

Gholamhoseiuni, M. and Bagheri, F. (2018). Zeolite Applications in Agriculture. *JOJ Hortic Arboric*, 1(1), pp. 1–2.

Ghorbani, M., Amirahmadi, E., Konvalina, P., Moudry, J., Barta, J., Kopecky, M., Teodorescu, R. I., and Bucur, R. D. (2022). Comparative Influence of Biochar and Zeolite on Soil Hydrological Indices and Growth Characteristics of Corn (*Zea Mays* L.). *Water*, 14(21), pp. 3506.

Havlin, J. L., Tisdale, S. L., Nelson, W. L., and Beaton, J. D. (2019). *Soil Fertility and Fertilizer: An Introduction to Nutrient Management*. India: Pearson India Education Service Pvt. Ltd.

Hue, N. (2020). Biochar for Maintaining Soil Health. In: Hue, N., ed., *Soil Biology*. Switzerland: Springer, pp. 21–46.

Jimayu, G. (2021). Review on Production and Importance of Basil (*Ocimum Basilicum* L) and Roles of Fertilizer on Basil Yield. *Journal of Biology, Agriculture and Healthcare*, 11(9), pp. 39–47.

Juskevicien'e, D., Radzeviˇcius, A., Viškelis, P., Maroˇckien˙e, N., and Karkleliene, R. (2022). Estimation of morphological features and essential oil content of basils (*Ocimum basilicum* L.) grown under different conditions. *Plants*, 11, pp. 1–12.

Karam, D. S., Nagabovanalli, P., Rajoo, K. S., Ishak, C. F., Abdu, A., Rosli, Z., Muharam, F. M., and Zulperi, D. (2022). An Overview on the Preparation of Rice Husk Biochar, Factors Affecting Its Properties, and Its Agriculture Application. *Journal of the Saudi Society of Agricultural Science*, 21(3), pp. 149–159.

Karhu, K., Kalu, S., Seppanen, A., Kitzler, B., and Virtanen, E. (2021). Potential of Biochar Soil Amendments to Reduce N Leaching in Boreal Field Conditions Estimated Using the Resin Bag Method. *Agriculture, Ecosystems and Environment*, 316, pp.1–10.

Kavitha, B., Reddy, P.V.L., Kim, B., Lee, S.S., Pandey, S.K., and Kim, K. H. (2018). Benefits and Limitations of Biochar Amendment in Agricultural Soils: A Review. *J. Environ. Manag*, 227, pp. 146–154.

Kolega, S., Moreno, B. M., Buffagni, V., Lucini, L., Valentinuzzi, F., Maver, M., Mimmo, T., Trevisan, M., Pii, Y., and Cesco, S. (2020). Nutraceutical Profiles of Two Hydroponically Grown Sweet Basil Cultivars as Affected by the Composition of the Nutrient Solution and the Inoculation with Azospirillum Brasilense. *Frontiers in Plant Science*, 11, pp. 1–17.

Krol, M. (2020). Natural Vs. Synthetic Zeolites. *Crystals*, 10, pp. 1–8.

Kumar, S., Seepau, R., Small, I. M., George, S., O'Brien, G. K., Marois, J. J., and Wright, D. L. (2021). Interactive Effects of Nitrogen and Sulfur Nutrition on Growth, Development, and Physiology of *Brassica Carinata* A. Braun and *Brassica Napus* L. *Sustainability*, 13, pp. 1–19.

Larimi, S. B., Shakiba, M., Mohammadinasab, A. D., and Vahed, M. M. (2014). Changes in Nitrogen and Chlorophyll Density and Leaf Area of Sweet Basil (*Ocimum Basilicum* L.) Affected by Biofertilizer and Nitrogen Application. *International Journal of Biosciences*, 5(9), pp. 256–265.

Li, H., An, S., Zhang, L. H., Peng, Ma, W., Meng, X., and Ye, H. (2021). Urea Fertilizer with Precisely Regulable Slow-Release Performance by Complexing with Random Copolyester. *Journal of Environmental Chemical Engineering*, 9, 1–7.

Li, X., Xu, Neupane, A., Abdoulmomumine, N., Debruyn, J. M., Walker, F. R., and Jagadamma, S. (2021). Co-Application of Biochar and Nitrogen Fertilizer Reduced Nitrogen Losses from Soil. *Plos ONE.* 16(3), pp. 1–17.

Minhal, F., Ma'as, A., Hanudin, E., and Sudira, P. (2019). Imporvement of the Chemical Properties and Buffering Capacity of Coastal Sandy Soil as Affected by Clay and Organic By-Product Application. Soil and Water Research, 15(2), pp. 93–100.

Moshoeshoe, M., Nadiye-Tabbiruka, M. S., and Obuseng, V. (2017). A Review of the Chemistry, Structure, Properties and Applications of Zeolites. *Am. J. Mater. Sci*, 7, pp. 191–221.

Narayan, O. M., Kumar, P., Yadav, B., Dua, M., and Johri, A. K. (2022). Sulfur Nutrition and Its Role in Plant Growth and Development. *Plant Signaling & Behavior*, pp. 1–11.

Prakongkep, N., Gilkes, R., Wisawapipat, W., Leksungnoen, P., Kerdchana, C., et al. (2020). Effects of Biochar on Properties of Tropical Sandy Soils Under Organic Agriculture. *Journal of Agricultural Science*, 13 (1), pp. 1–17.

Ngezimana, W. and Agenbag, G. A. (2014a). The Effect of Nitrogen and Sulphur on the Grain Yield and Quality of Canola (*Brassica Napus* L.) Grown in the Western Cape, South Africa. *South African Journal of Plant and Soil*, 31(2), pp. 69–75.

Ngezimana, W. and Agenbag, G. A. (2015). The Effect of Nitrogen and Sulphur on the Agronomical and Water Use Efficiencies of Canola (*Brassica Napus* L.) Grown in Selected Localities of the Western Cape Province, South Africa. *South African Journal of Plant and Soil*, 32(2), pp. 71–76.

Nyambo, P., Taeni, T., Chiduza, C., and Araya, T. (2018). Effects of Maize Residue Biochar Amendments on Soil Properties and Soil Loss on Acidic Hutton Soil. *Agronomy*, 8, pp. 256.

Oliveira, M., Moura, G. M., Zardetto, G., Cardoso, B. K., Alves, A. A. R., Tsukui, A., Rezende, C. M., Cortez, L. E. R., Cortez, D. A. G., Piau Júnior, R., Alberton, O., and Gazim, Z. C. (2014). Effect of Sulphur on Yield and Chemical Composition of Essential Oil of *Ocimum basilicum* L. *African Journal of Agricultural Research*, 9(7), 688–694.

Oshunsanya, S. (2019). Introductory Chapter: Relevance of Soil pH to Agriculture. In: Oshunsanya, S., *Soil pH for Nutrient Availability and Crop Performance*. IntechOpen.

Otto, R., Ferraz-Almeida, R., Soares, J. R., Carneiro, P. V., Coser, T. R., Horowitz, N., Soares, L. C., Novaes, G. B., Vargas, V. P., and Holzschuh, M. J. (2023). Nitrogen Fertilizer Management on Cotton (*Gossypium hirsutum* L.) Yield and Quality in Two Tropical Soils. *European Journal of Agronomy*, 142, pp. 1–12.

Pariyar, P., Kumari, K., Jain, M. K. and Jadhao, P. S. (2020). Evaluation of Change in Biochar Properties Derived from Different Feedstock and Pyrolysis Temperature for Environmental and Agricultural Application. Science of Total Environment, 713, pp. 1–16.

Rawat, J., Saxena, J., and Sanwal, P. (2019). Biochar: A Sustainable Approach for Improving Plant Growth and Soil Properties. In: Rawat, J., Saxena, J., and Sanwal, P., ed., *Biochar-An Imperative Amendment for Soil and the Environment*. IntechOpen.

Renata, N. (2013). Does Mineral Fertilization Modify Essential Oil Content and Chemical Composition in Medicinal Plants?. *Acta Scientiarum Polonorum-Hortorum Cultus*, 12(5), pp. 3–16.

Sampaio, I. M. G., Guimarães, M. De A., Rabelo, J. Da S., Viana, C. Dos S., and Machado, F. G. A. (2021). Productive and Physiological Responses of Basil to Nitrogen Fertilization. *Horticultura Brasileira*, 39(3), pp. 335–340.

Shareef, T.M.E. and Zhao, B.W. (2017) Review Paper: The Fundamentals of Biochar as a Soil Amendment Tool and Management in Agriculture Scope: An Overview for Farmers and Gardeners. *Journal of Agricultural Chemistry and Environment*, 6, pp. 38–61.

Souri, M. K., Naiji, M., and Kianmehr, M. H. (2019). Nitrogen Release Dynamics of a Slow Release Urea Pellet and Itseffect on Growth, Yield, and Nutrient Uptake of Sweet Basil (*Ocimum Basilicum* L.). Journal of Plant Nutrition, 42(6), pp. 604–614.

Teuber, O., Samarappuli, D., and Berti, M. (2020). Nitrogen and Sulfur Fertilization in Kale and Swede for Grazing. *Agronomy*, 10, pp. 1–17.

Torma, S., Vilcek, J., Adamisin, P., Huttmanova, E., and Hronec, O. (2014). Influence of Natural Zeolite on Nitrogen Dynamics in Soil. Turkish Journal of Agricultural and Forestry, 38, pp. 739–744.

Vilanova, C. M., Coelhob, K. P., Luza, T. R. S. A., Silveiraa, D. P. B., Coutinhoa, D. F., and Moura, E. G. (2018). Effect of Different Water Application Rates and Nitrogen Fertilisation on Growth and Essential Oil of Clove Basil (*Ocimum gratissimum* L.). Industrial Crops & Products, 125, pp. 186–197.

Walia, S. and Kumar, R. (2021). Nitrogen and Sulfur Fertilization Modulates The Yield, Essential Oil and Quality Traits of Wild Marigold (*Tagetes minuta* L.) in the Western Himalaya. *Frontiers in Plant Science*, 11, pp. 1–17.

Wang, H., Kobke, S., and Dittert, K. (2020). Use of Urease and Nitrification Inhibitors to Reduce Gaseous Nitrogen Emissions from Fertilizers Containing Ammonium Nitrate and Urea. *Global Ecology and Conservation*, 22, pp, 1–11.

Widhiyanuriyawan, D. and Hamidi, N. (2013). Variasi Temperatur Pemanasan Zeolite Alam-NaOH untuk Pemurnian Biogas. *Jurnal Energi dan Manufaktur*, 6(1), pp. 1–11.

Zenda, T., Liu, S., Dong, A., and Duan, H. (2021). Revisiting Sulphur—The Once Neglected Nutrient: It's Roles in Plant Growth, Metabolism, Stress Tolerance and Crop Production. *Agriculture*, 11, pp. 1–24.

Zimmerma, A.R. and Gao, B. (2013). The Stability of Biochar in the Environment. In: Ladygina N, Rineau F., ed., *Biochar and Soil Biota*. Boca Raton: CRC Press, pp. 1–40.