

Research Paper

Zeolite Amended Coastal Sandy Soils Improve Nitrogen Use Efficiency in Maize Vegetative Growth

Fahmi Budiayanto

Universitas Muhammadiyah Yogyakarta, Indonesia

*Corresponding author: fhmibudi@umy.ac.id

ARTICLE INFO

Keywords
Coastal Sandy Soils
Nitrogen Use Efficiency
Sustainable Soil
Zeolite Amendment

Received: 15 September
2025

Revised: 30 October 2025

Accepted: 20 November
2025

Available online: 21
December 2025

ABSTRACT

Coastal sandy soils are characterized by low nutrient retention and high nitrogen (N) losses, which limit crop productivity and reduce nitrogen use efficiency (NUE). This study aimed to evaluate the effect of zeolite amendment on nitrogen use efficiency and vegetative growth of maize cultivated in coastal sandy soils. A controlled field experiment was conducted using a randomized block design with different rates of zeolite application combined with nitrogen fertilizer. Parameters observed included plant height, leaf number, leaf area, chlorophyll content, biomass accumulation, and nitrogen uptake during the vegetative growth stage. The results showed that zeolite-amended soils significantly improved soil cation exchange capacity and reduced nitrogen leaching, leading to higher nitrogen availability for plant uptake. Consequently, maize grown in zeolite-treated plots exhibited significantly enhanced vegetative growth and higher NUE compared to the control without zeolite. The highest zeolite application rate resulted in optimal nitrogen uptake and biomass production. These findings indicate that zeolite amendment is an effective soil management strategy to enhance nitrogen use efficiency and improve maize vegetative growth in coastal sandy soils, contributing to more sustainable and efficient fertilizer use in coastal agricultural systems.

Copyright © 2025 Authors

This is an open access article under [CC-BY 4.0](https://creativecommons.org/licenses/by/4.0/) license



Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops worldwide and plays a crucial role in food security, feed supply, and agro-industrial raw materials. However, maize productivity is highly dependent on nitrogen (N) availability, as nitrogen is a key nutrient required for vegetative growth, chlorophyll formation, and biomass accumulation. In coastal agricultural areas, maize cultivation often faces serious constraints due to the dominance of sandy soils, which are characterized by low organic matter content, poor nutrient-holding capacity, and high susceptibility to nutrient leaching. Coastal sandy soils typically exhibit low cation exchange capacity and weak nutrient retention, resulting in inefficient use of nitrogen fertilizers. A large proportion of applied nitrogen is lost through leaching and volatilization, leading to low nitrogen use efficiency (NUE), increased production costs, and potential environmental pollution. Improving nitrogen retention and availability in such soils is therefore essential to enhance maize growth and achieve more sustainable crop production systems.

Zeolite has gained increasing attention as a soil amendment due to its unique physicochemical properties, including high cation exchange capacity, porous structure, and strong ability to adsorb ammonium ions. When applied to sandy soils, zeolite can reduce nitrogen losses by retaining ammonium in the soil matrix and gradually releasing it for plant uptake. This mechanism has the potential to improve nitrogen use efficiency and support better vegetative growth in maize, particularly under conditions where nutrient losses are high. Despite the growing interest in zeolite-based soil amendments, studies focusing on their effectiveness in improving nitrogen use efficiency and maize vegetative growth in coastal sandy soils remain limited. Therefore, this study aims to evaluate the impact of zeolite amendment on nitrogen use efficiency and vegetative growth performance of maize grown in coastal sandy soils. The findings of this research are expected to provide scientific evidence for the use of zeolite as a sustainable soil management strategy to enhance fertilizer efficiency and maize productivity in coastal agricultural environments.

Coastal sandy soil is one form of marginal land that has low productivity. This type of soil contains low available nutrients and has a low ability to store water due to the dominance of sand fraction. Low clay mineral and organic matter content cause the soil not to form aggregates, with a weak structure or even without structure (Bruand et al., 2014), so it does not have soil colloids as nutrient binding complexes. The coastal sandy soil area of Bugel beach Ku-lon Progo is part of more than 10,000 hectares of sandy beach stretching along the southern coast of Bantul and Kulon Progo. Bugel sandy beach has an area of around 3,000 hectares, and some parts of the area have been used by residents to cultivate various types of agricultural commodities such as watermelons, chilies, corn, and vegetables. One of the main problems of these soils is the low moisture content due to their high infiltration capacity and soil permeability. This condition causes the water not to be able to remain in the pores of the soil, moving out of the rooting zone. This process results in low moisture content in the root zone, thus cannot support plant growth. Hoa et al. (2010) state that sandy soils have many factors that limit agricultural production, including nutrient short-ages and low water storage capacity.

Soil dominated by sand fraction with low clay mineral and organic matter content has high porosity and easily escapes water out of the root zone. Therefore, crop cultivation in coastal sand has low nitrogen fertilization efficiency, which is due to the unavailability of colloidal complexes of soils capable of binding nitrogen ions of the fertilizer. Dry coastal

sandy soil conditions make the root zone space aerobic and stimulate the transformation of ammonium ions into nitrate ions in the soil solution system, making it easily leached (Budiyanto, 2016). This nitrogen leaching process is an obstacle to successful nitrogen fertilization in coastal sandy soils. The productivity of sandy soil can be improved by adding materials that can increase water storage capacity. Some treatments include the addition of clay minerals, application of organic matter, mulching, and the use of other materials that can store water. The treatments aim to improve the status of water in the root zone and reduce the rate of gravity water so that it can support the nutrient uptake process. The improvement can also be achieved by adding a soil amendment that can bind water and nutrients and gradually free up nutrients for plants to absorb. Utilization of hydrogel as a soil amendment material in sandy soil by Akhter et al. (2004) proved that the material could delay plant wilting and increase soil moisture content. In addition, Tahir and Marschner (2016) used clay minerals as soil ameliorant that was proven to increase crop production in sandy soils.

One of the soil amendment materials is zeolite rock, a form of a hydrated alumina-silicate compound that has multi structural properties. This mineral has water-absorbing properties and acts as ion exchange. Zeolite can be used in agriculture as a soil softener, nutrient carrier, regulator of nutrient release in soil, and agent to increase the diversity of microorganisms in the soil (Sugiarti and Amiruddin, 2008; Sangeetha and Baskar, 2016; Mahesh et al., 2018). Furthermore, the Director-General of Food Crops and Horticulture (1998) states that zeolite is able to increase the solubility of dissolved oxygen in paddy fields, maintain soil pH stability, and fix heavy metals such as Pb and Cd. The addition of zeolite causes the soil to retain fertilizer cations (NH_4^+ -urea and K^+ -KCl), thereby making them not easily leached by the movement of gravity water as well as increasing soil CEC and crop yields. In addition, the application of zeolite can also increase nutrient uptake of nitrogen and phosphorus in rice cultivation. (Zheng et al., 2019; Wu et al., 2019). emergence of primordial flowers. Growth variables observed were plant height, plant stem diameter, and fresh weight and dry weight of plant biomass. The data obtained were analyzed using analysis of variance, followed by Duncan's multiple range test at a level of 5%.

Method

In this research, coastal sandy soils were used as planting media, which were taken from Bugel beach Kulon Progo at a depth of 40 cm. Meanwhile, zeolite rocks were mined from Playen Gunung Kidul. The research was conducted from April to August 2019 in the experimental field of the Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta. The research was carried out using the green-house experiment method, arranged in a completely randomized factorial design (Harsojuwono et al., 2011). The first factor was activated zeolite rock doses, consisting of 7 levels, namely 0% (Z0), 1% (Z1), 2% (Z2), 3% (Z3), 4% (Z4), 5% (Z5), and 6% (Z6) per 10 kg of sandy soils as planting media. The second factor was nitrogen fertilizer doses, consisting of 3 levels, namely 75 kg (N1), 100 kg (N2), and 125 kg (N3) per hectare. There were four replications within each treatment combination, resulting in a total of 84 experimental units. Observation on the growth variables of the corn plants was performed eight weeks after planting or during the vegetative growth phase marked

by the data obtained were analyzed using analysis of variance, followed by Duncan's multiple range test at a level of 5%.

This study was conducted using an experimental approach to evaluate the effect of zeolite amendment on nitrogen use efficiency and vegetative growth of maize cultivated in coastal sandy soils. The research was carried out in a coastal agricultural area characterized by sandy soil texture, low organic matter content, and high permeability. The experiment was implemented during the main growing season under field conditions. The experimental design used was a randomized block design with several treatments consisting of different zeolite application rates combined with a uniform nitrogen fertilizer dose. Each treatment was replicated to ensure data reliability. Zeolite was incorporated into the soil prior to planting to allow adequate interaction with soil particles. Nitrogen fertilizer was applied according to recommended agronomic practices, with split applications during the early vegetative growth stages. Maize seeds were planted at standard spacing, and crop management practices such as irrigation, weed control, and pest management were carried out uniformly across all plots. Observations focused on the vegetative growth stage and included measurements of plant height, number of leaves, leaf area, chlorophyll content, and above-ground biomass. Soil samples were collected to assess changes in soil chemical properties, particularly nitrogen availability and cation exchange capacity.

Results and Discussion

The effect of zeolite application on water and nitrogen availability can be observed from the vegetative growth of corn plants at eight weeks after planting. The analysis of variance indicated that there was no significant interaction effect of the zeolite and nitrogen fertilizer doses on the plant height (Table 1).

Table 1. Plant Height (cm) at Eight Weeks After Planting

Zeolite doses (%)	Nitrogen fertilizer doses			Mean
	N1 (75 kg/h)	N2 (100 kg/h)	N3 (125 kg/h)	
Z0 (0)	66.45	78.75	86.50	77.23 e
Z1 (1)	95.70	112.25	100.75	102.90 d
Z2 (2)	110.20	124.70	125.75	120.22 c
Z3 (3)	124.50	126.75	135.00	128.75 bc
Z4 (4)	115.25	128.25	148.70	130.73 bc
Z5 (5)	115.10	128.75	158.50	134.12 b
Z6 (6)	150.20	168.20	176.75	165.05 a
Mean	111.06 q	123.93 p	133.14 p	(-)

Remarks: Means followed by the same letters in the same column are not significantly different based on DMRT at α 5%.

Table 2. Stem Diameter (cm) at Eight Weeks After Planting

Zeolite doses (%)	Nitrogen fertilizer doses			Mean
	N1 (75 kg/h)	N2 (100 kg/h)	N3 (125 kg/h)	
Z0 (0)	1.10	1.20	1.18	1.16 c
Z1 (1)	1.20	1.25	1.15	1.20 c
Z2 (2)	1.25	1.25	1.35	1.28 bc
Z3 (3)	1.28	1.30	1.35	1.31b
Z4 (4)	1.35	1.35	1.38	1.36 b
Z5 (5)	1.40	1.40	1.45	1.42 ab
Z6 (6)	1.45	1.45	1.75	1.55 a
Mean	1.29 p	1.31 p	1.37 p	(-)

Remarks: Means followed by the same letters in the same column are not significantly different based on DMRT at α 5%. Table 1 shows that increasing doses of zeolite can improve plant height. The application of 6% zeolite per weight of sandy soils resulted in the highest corn plants with a height of 165.05 cm. Likewise, increasing doses of nitrogen fertilizer up to 100 kg per hectare can also increase plant height. There was no interaction between zeolite and nitrogen fertilizer doses in affecting the growth of plant corn. Increasing the dose of zeolite is thought to increase water supply in the root zone and support the process of nitrogen nutrient uptake. The results of plant height measurements at an average dose of nitrogen fertilizer showed that the highest dose of zeolite (6% per weight of 10 kg of sandy soils) produced the highest plants. This result is following the result by Sangeetha and Baskar (2016), reporting that the application of zeolite as a soil amendment material could increase the availability of water for plants in sandy soil. Besides, zeolite is beneficial in reducing the leaching rate of N element because the negative charge side of the zeolite surface can bind NH_4^+ ions (Omar et al., 2015), and reduce the transformation process to NO_3^- mobile ions in the soil solution system.

The same result was also observed on the stem diameter of the corn plants. The doses of zeolite and nitrogen fertilizer did not give significant interaction effect on the stem diameter of the corn plants (Table 2). There was a significant effect of zeolite doses on the stem diameter of the corn plants. The application of 6% zeolite per weight of the sandy soils as planting media produced the largest stem diameter. Meanwhile, the doses of nitrogen fertilizer did not significantly affect the stem diameter of the corn plants. Tables 1 and 2 show that at various doses of nitrogen fertilizer, an increase in the dose of zeolite can increase the availability of water for the nitrogen uptake process that occurs in the root zone. Zeolite is a hydrated aluminum mineral that has a three-dimensional structure formed by the tetrahedral $(\text{SiO}_4)^{4-}$ and $(\text{AlO}_4)^{5-}$ structures. These three-dimensional structures are interconnected so that they have canals and tunnels, and are generally negatively charged so that they can bind cations (Sugiarti and Amiruddin, 2008; Lestari, 2010). Therefore, zeolite application can improve the ability of sandy soils to store water and improve nutrient balance in sandy soils (Al-Busaidi et al., 2008).

The observation on the fresh weight of corn biomass showed that there was a significant interaction effect of zeolite and nitrogen fertilizer doses on vegetative growth. The effect of the combined treatment of zeolite and nitrogen fertilizer doses is presented in Table 3.

Table 3. Fresh Weight of Corn Plant Biomass (gram) at Eight Weeks After Planting

Zeolite doses (%)	Nitrogen fertilizer doses			Mean
	N1 (75 kg/h)	N2 (100 kg/h)	N3 (125 kg/h)	
Z0 (0)	58.5 k	86.4 jk	110.6 ijk	85.2
Z1 (1)	121 hijk	156.6 efghi	202.1 cdefg	159.9
Z2 (2)	137.7 ghij	165.8 defghi	161.9 efghi	155.1
Z3 (3)	165.3 defghi	174.3 cdefghi	146.5 fghij	162.0
Z4 (4)	156.8 efghi	170.4 cdefghi	238.8 c	188.7
Z5 (5)	211.2 cdef	226.1 cde	234.4 cd	223.9
Z6 (6)	183.4 cdefgh	308.6 b	435.7 a	309.2
Mean	147.7	184.0	218.6	(+)

Remarks: Means followed by the same letters in the same column are not significantly different based on DMRT at α 5%. The application of nitrogen fertilizer at all doses (75, 100, and 125 kg per hectare) without zeolite treatment produced the lowest weight of fresh biomass compared to other treatment combinations. Meanwhile, the application of 100 and 125 kg of nitrogen fertilizer per hectare, when combined with 6% zeolite per weight of the growing media, produced higher biomass fresh weight than the application of 75 kg of nitrogen per hectare. The fresh weight of plant biomass is the weight of the entire plant tissues that have been developing for a certain time, along with the water contained. Plants that have better growth have cells containing more water. Table 3 shows that the treatment combination of zeolite and nitrogen fertilizer can improve the growth of plant cells and tissues. Zeolite can increase water supply and nitrogen nutrient uptake for the growth of plant cells and tissues. The addition of zeolite can suppress the rate of nitrification due to NH_4^+ ions and nitrogen leaching because it is bound by its specific surface (Ippolito et al., 2011), and this condition supports the process of nitrogen nutrient uptake of plants. The ability of zeolite to fix NH_4^+ ions and delay nitrification was also conveyed by Sudirja et al. (2016), reporting that mixing Urea and Zeolite (95:5) could increase the total nitrogen content of the soil.

Analysis of variance on the dry weight of plant biomass showed that there was no significant interaction effect of zeolite and nitrogen fertilizer doses on plant growth. However, each treatment significantly affected the dry weight of plant biomass (Table 4). Increasing the dose of zeolite can significantly increase the dry weight of plant biomass. These data show that the availability of water in the root zone will guarantee the process of nitrogen nutrient uptake for the growth and development of corn plant cells and tissues. It is suspected that increasing the zeolite dose can create water sorption complexes in the root

zone so that gravity water can be reduced, and the leaching of nitrogen compounds will also be reduced. The addition of zeolite turned out to be able to improve the insufficiency of sandy soil as a planting medium. The use of zeolite will increase water storage capacity and cation exchange capacity so that N-ammonium nutrients can be stored. Experiments carried out by Aina et al. (2017) showed that the use of zeolite in corn plantations could increase the biomass of corn plants cultivated using NPK. Another experi-

Table 4. Dry weight of corn plant biomass (gram) at eight weeks after planting

Zeolite doses (%)	Nitrogen fertilizer doses			Mean
	N1 (75 kg/h)	N2 (100 kg/h)	N3 (125 kg/h)	
Z0 (0)	9.65	12.80	14.78	12.41 d
Z1 (1)	17.90	21.85	22.24	20.66 c
Z2 (2)	23.54	24.78	24.90	24.41 bc
Z3 (3)	24.45	21.40	27.95	23.60 bc
Z4 (4)	25.35	29.45	23.15	25.98 b
Z5 (5)	26.46	26.18	33.18	28.61 b
Z6 (6)	32.90	37.45	50.75	40.37 a
Mean	22.89 q	24.84 q	28.14 p	(-)

Remarks: Means followed by the same letters in the same column are not significantly different based on DMRT at α 5%.

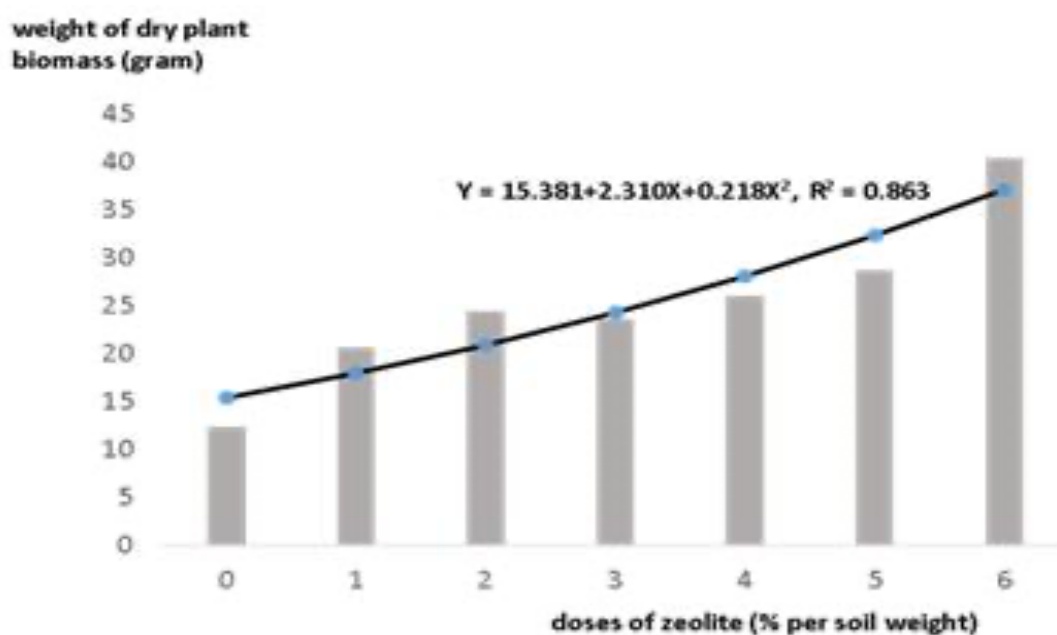


Figure 1. Effect of the Increasing Dose of Zeolite on the Dry Weight of Plant Biomass at Average Doses of Nitrogen Fertilizer

The dry weight of plant biomass is the net weight of photosynthesis, largely determined by how much nutrients the plant can absorb. The fertilizer dose of 125 kg per hectare produced the highest dry weight of plant biomass. On the other hand, 125 kg of nitrogen fertilizer per hectare is the optimum dose for the growth of corn plants. The comparison of the dry weight of plant biomass produced by the three treatments shows that the addition of nitrogen fertilizer up to a certain dose can guarantee a better growth of plant cells and tissue. Table 4 also shows that increasing the dose of zeolite at the average doses of nitrogen fertilizer can significantly increase the dry weight of plant biomass. The relationship between increasing zeolite dose at the average doses of nitrogen fertilizer and the increase of plant biomass dry weight is shown in Figure 1.

Figure 1 shows that at the average doses of nitrogen fertilizer, zeolite application can increase the dry weight of plant biomass. The presence of zeolite in the root zone proves to be able to increase water availability and nitrogen nutrient fixation, as well as to increase cell and plant tissue growth. The estimated curve on the effect of zeolite doses on plant biomass dry weight was formulated into a quadratic non-linear curve relationship pattern of $Y = 15.381 + 2.310X + 0.218X^2$ with a determinant coefficient (R^2) of 0.863. The curve shows that increasing the zeolite dose to above 6% per weight of the sandy soil could still increase the dry weight of plant biomass. The coefficient of determination of 0.863 indicates that an 86.3% increase in dry weight of plant biomass is determined by an increase in zeolite dose. The use of zeolite in the cultivation of annual crops such as mustard greens and sorghum can significantly increase the efficiency of nitrogen uptake (Bhaskoro et al., 2015; Suminarti, 2019).

Conclusion

This study demonstrates that the application of zeolite as a soil amendment in coastal sandy soils effectively improves nitrogen use efficiency and enhances the vegetative growth of maize. The incorporation of zeolite increased soil nutrient retention capacity, reduced nitrogen losses through leaching, and improved nitrogen availability for plant uptake. As a result, maize plants grown in zeolite-amended soils exhibited better vegetative performance, including increased plant height, leaf development, chlorophyll content, and biomass accumulation compared to plants grown without zeolite. Furthermore, higher nitrogen uptake and improved nitrogen use efficiency observed in zeolite-treated plots indicate that zeolite can optimize fertilizer utilization and reduce the need for excessive nitrogen inputs. These findings highlight the potential of zeolite amendment as a sustainable soil management strategy for maize cultivation in coastal sandy soils. The use of zeolite not only supports improved crop growth and productivity but also contributes to environmentally friendly and efficient nutrient management in coastal agricultural systems.

References

- Aina, N., Jumadi, O. dan Hiola S.F.(2017). Respon Pertumbuhan Jag-ung (*Zea mays*) dengan Pemberian Urea Bersalut Zeolit Sebagai Nitrogen Lepas Lambat. *Jurnal Bionature*, 7 (2): 152 – 162
- Akhter, J., Mahmood, K., Malik, K.A., Mardan, A., Ahmad, M. and Iqbal,(2004). Effects of Hydrogel Amendment on Water Storage of Sandy Loam and Loam Soils and Seedling Growth of Barley, Wheat and Chickpea. *Plant Soil Environ.*, 50 (10): 463 – 469

- Al-Busaidi, A., Yamamoto, T., Inoue, M., Eneji, A.E., Mori, Y. and Isrhad, M. (2008). Effects of Zeolite on Soil Nutrients and Growth of Barley Following Irrigation with Saline Water. The 3rd International Conference on Water Resources and Arid Environments and the 1st Arab Water Forum: 11p
- Bruand, A., C. Hartmann and G. Lesturgez. (2014). Physical Properties of Tropical Sandy Soils: A Large Range of Behaviours. https://www.researchgate.net/publication/228982691_Physical_properties_of_tropical_sandy_soils_A_large_range_of_behaviours. 10p
- Bhaskoro, A.W., Kusumarini, N. and Syekhfani. (2015). Efisiensi Pemupukan Nitrogen Tanaman Sawi pada Inceptisol melalui Aplikasi Zeolit Alam. Jurnal Tanah dan Sumberdaya Lahan, 2 (2) : 219 – 226
- Budiyanto, G. (2016). Pengendalian Pencucian Senyawa Nitrat Guna Meningkatkan Produktivitas Lahan Marginal Pantai Kulon Progo DIY. *Planta Tropika Journal of Agro Science*, 4 (1): 46– 57.
- Director-General of Food Crops and Horticulture. (1998). Pe-manfaatan Zeolit Sebagai Pengikat Urea. Publikasi No. PR.130.760.11
- Harsojuwono, B.A., Arnata I Wayan dan Puspawati, G.A.K.D., (2011). Rancangan Percobaan, Teori Aplikasi SPSS dan Excel. Penerbit Lintaskata. 147p
- Hoa, H.T.T., Cong, P.T., Tam, H.M., Chen, W. and Bell, R. (2010). Sandy soils in South Central Coastal Vietnam: Their Origin, Constraints and Management in 19th World Congress of Soil Science, Soil Solutions for a Changing World. 1 – 6 August 2010, Brisbane, Australia, 251-254
- Ippolito, J.A., Tarkalson, D.D. and Lehrs, G.A. (2011). Zeolite Soil Application Method Affects Inorganic Nitrogen, Moisture, and Corn Growth. *Soil Science*, 176 (3): 136 – 142
- Lestari, D.Y. (2010). Kajian Modifikasi dan Karakterisasi Zeolit Alam dari berbagai Negara. Prosiding Seminar Nasional Kimia dan Pendidikan Kimia 2010. www.kimia.uny.ac.id.
- Mahesh, M., Thomas, J., Kumar, K.A., Bhopale, B.S., Suresh, N.V., Vaid, S.K. and Sahu, S.K. (2018). Zeolite Farming: A Sustainable Agricultural Perspective. *International Journal of Current Microbiology and Applied Sciences*, 7 (5): 2912 – 2924
- Omar, L., Ahmed, O.H., and Majid, N.M.A. (2015). Improving Ammonium and Nitrate Release from Urea Using Clinoptilolite Zeolite and Compost Produced from Agricultural Wastes. *Hindawi Publishing Corporation Scientific World Journal*, 2015:12
- Sangeetha, C. and Baskar, P. (2016). Zeolite and its Potential Uses in Agriculture: A critical review. *Agricultural Reviews*, 37 (2): 101-108
- Sudirja, R., Joy, B., Rosniawaty, S., Setiawan, A. dan Yunianto, R.I. (2016). Pengaruh Formula Pupuk Urea-Zeolit-Arangaktif terhadap pH, N-total, KTK tanah dan Residu Pb pada Tanah Tercemar Limbah Industri. *Soilrens*, 14 (1): 16 – 22
- Sugiarti dan Amiruddin, S.Z. (2008). Pengaruh Jenis Aktivasi terhadap Kapasitas Adsorpsi Zeolite pada Ion Kromium. *Jurnal Chemica*, 4 (2): 20-25
- Suminarti, N.E. (2019). Dampak Pemupukan N dan Zeolit pada Pertumbuhan serta Hasil Tanaman Sorgum (*Sorghum bicolor* L.) Var. Super 1. *Jurnal Agro*, 6 (1): 1 – 14
- Tahir, S. and Marschner, P. 2016. Clay Addition to Sandy Soil - Effect of Clay Concentration and Particle Size on Microbial Biomass and Nutrient Dynamics after Addition of Low C/N ratio Residue. *Journal Soil Science and Plant Nutrition* 16 (4): 864– 875

- Widyanto, A., Sebayang, H.T. and Soekartomo, S.2013. Pengaruh Pengaplikasian Zeolit dan Pupuk Urea pada Pertumbuhan dan Hasil Tanaman Jagung Manis (*Zea mays* L. *saccharata* Sturt.). Jurnal Produksi Tanaman, 1 (4): 378 – 388
- Wu,Q., Chi,D., Xia, G., Chen, T., Sun, Y. and Song, Y. 2019. Effects of Zeolite on Drought Resistance and Water–Nitrogen Use Efficiency in Paddy Rice. Journal of Irrigation and Drainage Engineering, 54 (11): 04019024
- Zheng, J., Chen, T., Chi, D., Xia ,G., Liu, G., Chen, W., Meng, W., Chen, Y. and Siddique, K.H.M. (2019). Influence of Zeolite and Phos-phorus Applications on Water Use, P Uptake and Yield in Rice under Different Irrigation Managements. Agronomy 9 (9): 537