Application of Soil Conditioner, Nutrient Solution with Biofertilizer to Improve Soil Bio-chemical Properties on Red Chili Plant

Betty Natalie Fitriatin[1], Envry Artanti Duidahayu Putri[2], Tualar Simarmata[1]

[1] Departemen Ilmu Tanah dan Sumber daya Lahan, Fakultas Pertanian Universitas Padjadjaran
[2] Program Studi Agroteknologi, Fakultas Pertanian Universitas Padjadjaran
Jl. Raya Bandung Sumedang Km 21 Jatinangor
Korespondensi: betty.natalie@unpad.ac.id

ABSTRACT

Plant productivity is influenced by soil quality and availability of plant nutrients. Soil conditioner can improve soil quality by enhancing soil properties. Both macro and micronutrients can be fulfilled through application of nutrient solution containing macro and micronutrients and biofertilizer. This experiment was conducted from at experimental field of the Faculty of Agriculture, Universitas Padjadjaran to test the combination of soil conditioner, NPK fertilizer, nutrient solution (NS), and biofertilizer (BF) effects on soil biological and chemical properties and red chili growth. The experiment was designed using a Randomized Block Design with seven treatments and four replications. The treatments consisted of control, combination of NPK and NS with a dose of 0, 6, and 12 kg.ha^{-1} BF contained Azotobacter sp., Azospirillum sp., and Pseudomonas sp.. The doses used for a single application were 15 gplant-1 NPK and 300 mLplant-1 NS. Manure was applied to the control treatment and soil conditioner to the other treatments as a basic fertilizer at a dosage of 4 ton.ha^{-1}. The results showed that the combination of soil conditioner, NPK fertilizer, nutrient solution, and biofertilizer had significant effects on soil biological properties and red chili growth, but didn't show significant effect on soil chemical properties. The combination of soil conditioner + NPK + 12 kg.ha^{-1} BF increased soil fungal population (113,4 x 103 CFU.mL^{-1}) and bacterial population (599,5 x 108 CFU.mL^{-1}). Meanwhile, the combination of soil conditioner + NS + 6 kg.ha^{-1} BF increased plant height (60,48 cm).

Keywords: Doses, nutrients, plant productivity, soil quality

1. INTRODUCTION

Red chili (*Capsicum annuum* L.) is a horticultural commodity that is highly demanded among Indonesian citizens to use as a seasoning. Red chili production can decrease due to low soil fertility, unsuitable planting environment and fertilization factors (Adhiana, 2021). Inceptisols is a dominant soil order in the West Java which generally has a low level of fertility, pH, C-organic content, cation exchange capacity (CEC), N, and P (Subagyo et al., 2000), thus requiring an improvement in soil quality, because soil quality will affect plant productivity.

Soil conditioner can improve soil quality by improving soil properties. Soil conditioner that are often used to improve Inceptisols soil properties are soil conditioner. Giving soil conditioner in the form of dolomite and guano can improve soil biological and chemical properties, such as pH, soil organic carbon (SOC), soil bacterial activity, and can increase the yield of chili plants (Sudirja *et al.*, 2017; Subatra, 2013). According to Situmorang *et al.* (2019) the application of 4 ton.ha^{-1} cow manure, coconut shell biochar, dolomite, and guano on Inceptisols soil can increase SOC, soil pH, phosphate solubilizing bacteria population, and increase chili plant yield by 44,9%.

The increased productivity of agricultural land is also influenced by the availability of plant nutrients that can be fulfilled optimally through fertilization. The application of NPK fertilizer can increase the productivity of red chili plants by increasing plant height, number and weight of fruits per chili plant (Diana & Hendarto, 2018; Hendarto et al., 2021). However, the application of NPK fertilizer to plants can only meet the needs of macro nutrients of plants, so other sources of nutrient are needed that can meet the macro and micro nutrients of plants, such as nutrient solution.

Nutrient solution is an inorganic fertilizer adopted by the hydroponic system that contains macro and micro nutrients needed by plants during their growth and development process (Purba & Padhilah, 2021; Hidayanti &

Kartika, 2019). The use of nutrient solution in chili plants can make it easier for plants to absorb nutrients because nutrients are given in the form of solutions, so that macro and micro nutrients needed in plant growth can be more quickly available. The use of inorganic fertilizer in the long term can have negative impacts, including pollution of soil, water, and air, and impacts on human health (Ajmal et al., 2018). The application dose of inorganic fertilizer can be reduced by combining inorganic fertilizer with biofertilizer (Chandini et al., 2019).

Biofertilizer contain microbes as nutrient providers in the soil (Simanungkalit et al., 2006). Microbes in biofertilizer have the ability to provide nutrients, inhibit disease growth, and increase soil microbial population (Kumar et al., 2017). Soil microbes play a role in the process of decomposing organic matter, releasing nutrients into plant-available forms, and degrading toxic residues (Kalay et al., 2019). The increase in soil microbial activity is closely related to soil chemical properties, namely the CEC value and SOC content, because the increase in CEC value and SOC content is influenced by organic matter from the decomposition process by soil microbes (Singh et al., 2023).

Some research results show that bacteria in biofertilizer play an important role in promoting plant growth, including *Azotobacter* sp. and *Azospirillum* sp. which roled as nitrogen fixing bacteria and *Pseudomonas* sp. which roled as phosphate solubilizing bacteria (Esmaeilian et al., 2022). *Azotobacter* sp. plays a role in nitrogen fixation, phytohormone production, and exopolysaccharides that can make plants more drought tolerant and increase antimicrobial and antifungal resistance (Vikhe, 2014; Hindersah et al., 2018). *Azospirillum* sp. is a soil microbe that can promote plant growth and yield by fixating nitrogen, producing the IAA hormone, and increasing nutrient absorption for plants (Hernandez et al., 2022). *Pseudomonas* sp. is a phosphate solubilizing soil microbial and producer of the IAA phytohormone which can promote plant growth (Izzah et al., 2017). The combination of soil conditioner, NPK fertilizer or nutrient solution (NS) with biofertilizer (BF) contained consortium of *Azotobacter* sp., *Azospirillum* sp., and *Pseudomonas* sp. is expected to improve soil quality and red chili growth.

2. MATERIALS AND METHODS

The experiment was conducted from July to November 2022 at Bale Tatanen experimental field, Faculty of Agriculture, Universitas Padjadjaran, at an altitude of ± 700 meters above sea level (masl). Soil biological analysis was conducted at the Soil Biology Laboratory, while soil chemical analysis was conducted at the Soil Chemistry and Plant Nutrition Laboratory, Department of Soil Science and Land Resources, Faculty of Agriculture, Universitas Padjadjaran.

2.1 Tools and Materials

The tools used in this experiment, including hoes, tractors, soil sieves, mulch punchers, digital scales, buckets, measuring cups, trays with a size of 12 x 6 holes, stakes, water drums, sprayers, rulers, total dissolved solid (TDS) meter, analytical balance, sterile pipettes of 1 and 10 mL, sterile test tubes of 18 mL, petri dishes, glass bottles, bunsen, vortex, shaker bottle, shaking machine, filter paper, Kjeldahl tube, 250 mL erlenmeyer, distillator, and burette.

Materials used in this experiment, including red chili seeds var. Baja F1, husk charcoal, Jatinangor Inceptisols soil, black and silver plastic mulch, cow manure, soil conditioner (40% coconut shell biochar, 35% blotong compost, 15% dolomite, and 10% guano), NPK fertilizer (urea, SP-36, KCl), nutrient solution, biofertilizer (20% consortium of *Azotobacter* sp., *Azospirillum* sp., *Pseudomonas* sp. and 80% carrier material in the form of compost and peat), labels, rope, soil samples, distilled water, 0,85% NaCl solution (physiological), potato dextrose agar media, nutrient agar media, plastic wrap, antibiotics (chloramphenicol), ammonium acetate 1 N, boric acid 1%, NaOH 40%, ethanol 96%, conway indicator, H_2SO_4 0,05 N, $K_2Cr_2O_7$ 1 N, H_2SO_4 concentrated, H_3PO_4 concentrated, diphenylamine indicator, and $FeSO_4$,5 N.

The Jatinangor Inceptisols soil used has a slightly acidic pH (5,83), low SOC content (1,66%), low N-total (0,18%), low C/N ratio (9,16), low CEC (11,78 $cmol.kg^{-1}$), and high base saturation (61,78%). The soil texture was clay with a fungal population of 10 x 10^3 $CFU.mL^{-1}$ and bacterial population of 4,34 x 10^8 $CFU.mL^{-1}$.

2.2 Experimental Design

The experiment was conducted using the Randomized Block Design (RBD) method with seven treatments and four replications, namely:

- Control (manure + NPK)
- Soil conditioner (SC) + nutrient solution (NS) + 0 $kg.ha^{-1}$ biofertilizer (BF)
- SC+ NS + 6 $kg.ha^{-1}$ BF
- SC + NS + 12 $kg.ha^{-1}$ BF
- SC + NPK + 0 $kg.ha^{-1}$ BF
- SC + NPK + 6 $kg.ha^{-1}$ BF
- SC + NPK + 12 $kg.ha^{-1}$ BF

The control treatment used in this experiment was a positive control in the form of conventional farmer fertilization. This experiment was conducted using 7 beds with a length x width of 9 x 1 m and a height of 30 cm. Each replicate was in a different bed and each replicate consisted of 4 red chili plants, so there were 28 chili plants in each bed planted in a zigzag manner using a spacing of 60 x 50 cm.

The application of manure and soil conditioner was given at 141 gplant-1 hole which was applied once during the preparation of the experimental land, after mulching the holes. The dose given in one application was 15 gplant-1 of NPK fertilizer which was given thrice in 30-day intervals (at the beginning of planting, 1 month after planting, and 2 months after planting), then 300 mLplant-1 of nutrient solution which was given twice in two-day intervals. The concentration of nutrient solution was increased periodically every week, starting from 700 ppm (1 week after planting), 800 ppm (2 weeks after planting), 1.000 ppm (3 weeks after planting), up to 1.300 ppm (4 weeks after planting) and so on. The application of biofertilizer was given thrice in a 30-day interval (at the beginning of planting and 1 month after planting) at a dose of 6 $kg.ha^{-1}$ (0,21 $g.plan^{t-1)}$ and 12 $kg.ha^{-1}$ (0,42 g. $plant^{-1}$).

Plant maintenance includes watering in the soil conditioner + NS + BF combination treatment using nutrient solution once every second or alternating with water application, while watering in other treatments is done every day using water. Weeding is done mechanically by pulling weeds around the planting area. Control of plant pest organisms was carried out by spraying fungicides made from propineb 70% and insecticides made from emamectin benzoate 20 $g.L^{-1}$ once a week since symptoms were seen in red chili plants and the use of attractants made from methyl eugenol 800 $g.L^{-1}$ and glumol adhesive glue.

Soil sampling was carried out twice, the first time before land preparation and the second time during the final vegetative phase. Variables observed in this experiment include soil biological properties, such as fungal population and bacterial population using the total plate count (TPC) method, soil chemical properties, such as soil CEC using the percolate distillation method and SOC using the Walkley-Black method analyzed in the final vegetative phase or at 5 weeks after planting (WAP), then observations of red chili plant height at 1-5 WAP observed by measuring plant height using a ruler.

Data analysis was performed statistically using SPSS software version 25 by performing the Shapiro-Wilk normality test. Normally distributed data were then subjected to analysis of variance test using a 5% significance level. If there is a significant effect, it is continued with the Duncan multiple range test (DMRT) at the 5% significance level.

3. RESULTS AND DISCUSSION

3.1 Soil Biological Properties

The results of statistical analysis (Table 1) showed that the application of soil conditioner, NPK fertilizer or nutrient solution with biofertilizer combination had significant effects on fungal population and bacterial population. Fungal population abundance in the control treatment increased compared to the initial soil analysis, from 10 x 10^3 CFU.mL^{-1} to 85 x 10^3 CFU.mL^{-1}. The p_7 treatment (soil conditioner + NPK + 12 kg. ha^{-1} BF) gave higher fungal population results than other treatments, which amounted to 113,4 x 10^3 CFU. mL^{-1} or increasing by 33,4% from the control treatment. The increase in fungal population can be caused by the biofertilizer in the treatment combination. This is in line with the research of Purwani et al. (2014) which showed that the application of biofertilizer produced the highest fungal population com-pared to the treatment without biofertilizer, because the microbes contained in biofertilizer help the decomposition process of organic matter which will be a source of energy for fungi to develop and carry out biological activities in the soil.

Table 1 Effect of Soil conditioner, NPK Fertilizer, Nutrient Solution (NS) with Biofertilizer (BF) Combination on Fungal Population and Bacterial Population

Treatments	Fungal Population (10^3 CFU.mL^{-1})	Increase (%)	Bacterial Population (10^8 CFU.mL^{-1})	Increase (%)
Control (manure + NPK)	85,0 ab	0,0	256,9 a	0,0
SC + NS + 0 kg.ha^{-1} BF	108,1 b	27,2	173,0 a	-32,7
SC+ NS + 6 kg.ha^{-1} BF	93,1 ab	9,5	234,4 a	-8,8
SC + NS + 12 kg.ha^{-1} BF	65,8 a	-22,6	379,5 ab	47,7
SC + NPK + 0 kg.ha^{-1} BF	66,6 a	-21,6	568,9 b	121,4
SC+ NPK + 6 kg.ha^{-1} BF	63,4 a	-25,4	519,4 b	102,2
SC + NPK + 12 kg.ha^{-1} BF	113,4 b	33,4	599,5 b	133,4

Notes: Numbers marked with the same letter are not significantly different according to Duncan's multiple range test at the 5% level.

Table 1 shown that the abundance of bacterial population in the control treatment increased compared to the initial soil analysis, from 4,34 x 10^8 CFU.mL^{-1} to 256,9 x 10^8 CFU.mL^{-1}. The p_7 treatment gave higher bacterial population results than the other treatments, which amounted to 599,5 x 10^8 CFU.mL^{-1} or an increase of 133,4% from the control treatment. The increase in bacterial population can be caused by the application of biofertilizer that contain a number of bacteria that can develop well, because they get food sources from organic matter contained in the applied soil conditioner and roled as a source of C (Simanungkalit et al., 2006).

Increased SOC content due to soil conditioner application can also increase microbial activity in the soil, so that microbial growth and development can take place optimally (Situmorang et al., 2019; Toago et al., 2017). Bacteria *Azotobacter* sp. and *Azospirillum* sp. contained in biofertilizer roled as non-symbiotic N fixers that can increase microbial populations in the soil, because N fixation activity in the root area increases. The element N is needed by bacteria as a source of protein that functions in biological processes such as the formation of bacterial cells.

3.2 Soil Chemical Properties

The results of statistical analysis (Table 2) showed that the application of soil conditioner, NPK fertilizer or nutrient solution with biofertilizer combination did not significantly affect the CEC value and SOC content. However, the CEC value and SOC content in all treatments were higher than the initial soil CEC value and SOC content before treatment, namely CEC 11,78 cmol.kg^{-1} and SOC 1,66%.

According to Wahyunto et al. (2016), the value of CEC and SOC content in accordance with the requirements of growing red chili plants, namely CEC > 16 cmol.kg^{-1} and SOC > 2%. Although the treatment given did not significantly affect the value of CEC and SOC content, the CEC and SOC content obtained after treatment were in accordance with the optimal growth requirements for red chili plants. The increase in soil CEC and SOC after treatment can occur because organic matter in soil conditioner undergoes a decomposition process with the help of microbes contained in biofertilizer (Mutammimah et al. 2018). Microbes in biofertilizer can accelerate the decomposition process of organic matter which produces soil colloids from humic compounds, so that it can increase soil CEC and SOC (Siregar et al., 2017). The increase in the negative charge of soil colloids from functional groups, such as carboxyl (-COOH) and hydroxyl (-OH) in organic matter can also cause an increase in soil CEC values

Table 2 Effect of Soil conditioner, NPK Fertilizer, Nutrient Solution (NS) with Biofertilizer (BF) Combination on Soil CEC Value and SOC Content

Treatments	CEC ($cmol.kg^{-1}$)	SOC (%)
Control (manure + NPK)	19,44	4,28
SC + NS + 0 $kg.ha^{-1}$ BF	19,42	4,28
SC+ NS + 6 $kg.ha^{-1}$ BF	17,72	4,92
SC + NS + 12 $kg.ha^{-1}$ BF	19,51	4,34
SC + NPK + 0 $kg.ha^{-1}$ BF	19,83	4,57
SC+ NPK + 6 $kg.ha^{-1}$ BF	20,06	4,96
SC + NPK + 12 $kg.ha^{-1}$ BF	17,55	4,94

Notes: Numbers are not given letter notation because the treatment does not significantly affect the response based on analysis of variance at the 5% level.

3.3 Kadar N Tanaman

The results of statistical analysis (Table 2) showed that the application of soil conditioner, NPK fertilizer or nutrient solution with biofertilizer combination had significant effects on red chili height at 1-5 WAP. The treatment of (soil conditioner + NS + 6 $kg.ha^{-1}$ BF) showed the highest plant height with a value of 60,48 cm at 5 WAP. Overall, the treatment with a combination of nutrient solutions produced higher plant height than the treatment that did not use nutrient solutions. This is because the nutrient solution contains macro and micro nutrients that greatly affect the growth of plant height.

Increasing the concentration of nutrient solution can optimize plant height growth, because there is an increase in the supply of nutrients to plants, especially N elements (Sianturi et al., 2021). The higher the concentration of nutrient solution, the higher the nutrient content (Subandi et al., 2015). The element N functions in the process of synthesizing amino acids and proteins in plants, and can stimulate overall plant growth. In addition to the N element, there are other elements in the nutrient solution that have an important role in the process of plant growth, namely Mn to support the absorption of N and Mo to bind N. Biofertilizer in the p_3 treatment also plays an important role in producing higher plant height than the control treatment, because *Azotobacter* sp. and *Azospirillum* sp. contained in biofertilizer have the ability to tether N, so as to increase and improve the content of N elements in the soil, and are able to produce phytohormones such as auxins and gibberellins as growth-promoting hormones (Kumar et al., 2017).

Table 3 Effect of Soil conditioner, NPK Fertilizer, Nutrient Solution (NS) with Biofertilizer (BF) Combination on Red Chili Plant Height

Treatments	Plant Height (cm)				
	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP
Control (manure + NPK)	26,68 ab	29,89 a	36,40 bc	44,25 bc	51,65 ab
SC + NS + 0 $kg.ha^{-1}$ BF	30,13 bc	34,34 bc	38,53 cd	46,88 bc	59,45 b
SC+ NS + 6 $kg.ha^{-1}$ BF	32,78 c	37,10 c	43,03 d	49,25 c	60,48 b
SC + NS + 12 $kg.ha^{-1}$ BF	23,65 a	31,53 ab	38,12 cd	45,45 bc	52,13 ab
SC + NPK + 0 $kg.ha^{-1}$ BF	24,13 a	28,05 a	31,45 ab	38,98 ab	47,34 a
SC+ NPK + 6 $kg.ha^{-1}$ BF	25,60 a	30,33 a	34,43 abc	41,98 abc	52,85 ab
SC + NPK + 12 $kg.ha^{-1}$ BF	24,88 a	28,13 a	30,95 a	33,55 a	44,95 a

Notes: Numbers marked with the same letter are not significantly different according to Duncan's multiple range test at the 5% level.

4. CONCLUSION

The combination of soil conditioner, NPK fertilizer or nutrient solution with biofertilizer had a significant effect in improving soil biological properties and red chili plant height, but had no significant effect on soil chemical properties. The combination of soil conditioner + NS + 6 $kg.ha^{-1}$ BF treatment is the dose that gives the best results on plant height (60,48 cm), while the combination of soil conditioner + NPK + 12 $kg.ha^{-1}$ BF treatment gives the best results on fungal population (113,4 x 10^3 $CFU.mL^{-1}$) and bacterial population (599,5 x 10^8 $CFU.mL^{-1}$) of soil.

REFFERENCES

Adhiana. 2021. Analisis faktor-faktor yang mempengaruhi produksi cabai merah. Jurnal Agrica Ekstensia. 15 (1): 82-92.

Ajmal, M., Ali, H. I., Saeed, R., Akhtar, A., Tahir, M., Mehboob, M. Z., & Ayub, A. 2018. Biofertilizer as an alternative for chemical fertilizers. Journal of Agriculture and Allied Sciences. 7 (1): 1-7.

Central Bureau of Statistics. 2020. Trade Distribution of Indonesian Red Chili Commodities. Jakarta: Central Bureau of Statistics. 114 pp.

Chandini, Kumar, R., & Prakash, O. 2019. The impact of chemical fertilizers on our environment and ecosystem. Research Trends in Environmental Sciences. 11 (2): 71-86.

Diana, R. A., & Hendarto, K. 2018. Uji efektivitas penggunaan pupuk NPK dan pupuk kandang terhadap pertumbuhan cabai merah (*Capsicum annuum* L.). Jurnal Agrica Ekstensia. 12 (1): 20-26.

Esmaeilian, Y., Amiri, M. B., Tavassoli, A., Calvo, A. C., & Comino, J. R. 2022. Replacing chemical fertilizers with organic and biological ones in transition to organic farming systems in saffron (Crocus sativus) cultivation. Chemosphere. 307 (1): 1-12. https://doi.org/10.1016/j.chemosphere.2022.135537.

Hendarto, K., Ginting, Y. C., Karyanto, A., & Amanda, V. C. 2021. Pengaruh dosis pupuk NPK dan jenis pupuk pelengkap terhadap pertumbuhan dan produksi cabai (*Capsicum annuum* L.). Jurnal Agrotropika. 20 (2): 81-92. https://doi.org/10.23960/ja.v20i2.5085.

Hernandez, M. A. C., Rivera, G., & Bocanegra-garc, V. 2022. *Azospirillum* spp. from plant growth-promoting bacteria to their use in bioremediation. Microorganisms. 10 (1057): 1-13. https://doi.org/10.3390/microorganisms10051057.

Hidayanti, L., & Kartika, T. 2019. Pengaruh nutrisi AB mix terhadap pertumbuhan tanaman bayam merah (*Amaranthus tricolor* L.) secara hidroponik. Sainmatika: Jurnal Ilmiah Matematika dan Ilmu Pengetahuan Alam. 16 (2): 166-175. https://doi.org/10.31851/ sainmatika.v16i2.3214.

Hindersah, R., Kalay, M., Talahaturuson, A., & Lakburlawal, Y. 2018. Bakteri pemfiksasi nitrogen *Azotobacter* sebagai pupuk hayati dan pengendali penyakit pada tanaman kacang panjang. Agric. 30 (1): 25–32.

Izzah, S., Rizwan, M., Baig, D. N., Saleem, Rahman Shahzaib Malik, K. A., & Mehnaz, S. 2017. Secondary metabolites production and plant growth promotion by Pseudomonas chlororaphis and P. aurantiaca strains isolated from cactus, cotton, and para grass. Journal of Microbiology and Biotechnology. 27 (3): 480–491. https://doi.org/https://doi.org/10.4014/jmb.1601.01021.

Kalay, A. M., Sesa, A., Siregar, A., & Talahaturuson, A. 2019. Efek aplikasi pupuk hayati terhadap populasi mikroba dan ketersediaan unsur hara makro pada tanah Entisol. Agrologia. 8 (2): 63–70. https://doi.org/10.30598/a.v8i2.1011.

Kumar, R., Kumawat, N., & Sahu, Y. K. 2017. Role of biofertilizers in agriculture. Popular Kheti. 5 (4): 63-66.

Mutammimah, U., Minardi, S., & Suntoro. 2018. Organic amendments effect on the soil chemical properties of marginal land and soybean yield. Journal of Degraded and Mining Lands Management. 7 (4): 2263-2268. https://doi.org/10.15243/jdmlm.2020.074.2263.

Purba, T., Situmeang, R., Rohman, H. F., Mahyati, Arsi, Firgiyanto, R., Junaedi, A. S., Tojibatus, S. T., Junairiah, Herawati, J., & Suhastyo, A. A. 2021. Pupuk dan Teknologi Pemupukan. Medan: Yayasan Kita Menulis. 150p.

Purwani, J., Erfandi, D., & Juarsah, I. 2014. Pengaruh pemupukan dan pembenah tanah terhadap populasi bakteri pada lahan sawah bekas tambang timah yang ditanami padi. Prosiding Seminar Nasional F-MIPA Universitas Terbuka. 53 (9): 38-46.

Sianturi, P. L. L., Manalu, C. J. F., & Marpaung, E. E. 2021. Pengaruh konsentrasi dan interval waktu pemberian pupuk cair AB mix terhadap pertumbuhan dan produksi tanaman cabai merah (*Capsicum annum* L.) di polibag. Majalah Ilmiah Methoda. 11 (1): 1-9. https://doi.org/10.46880/methoda.vol11no1.1-9.

Simanungkalit, R. D., Suriadikarta, D. A., Saraswati, R., Setyorini, D., & Hartatik, W. 2006. Pupuk Organik dan Pupuk Hayati. Bogor: Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. 312p.

Singh, S., Meerut, T., & Verma, S. K. 2023. Soil microorganisms and their role. The Agriculture Magazine. 2 (3): 179-182.

Siregar, P., Fauzi, & Supriadi. 2017. Pengaruh pemberian beberapa sumber bahan organik dan masa inkubasi terhadap beberapa aspek kimia kesuburan tanah Ultisol. Jurnal Agroekoteknologi. 5 (2): 256-264.

Situmorang, Y. E. G., Nurbaity, A., & Simarmata, T. 2019. Efek komposisi dan dosis amelioran terhadap sifat tanah dan hasil tanaman cabai (*Capsicum annuum* L.) pada Inceptisols. Jurnal Agrotek Indonesia 4 (1): 26-29.

Subagyo, H., Suharta, N., & Siswanto, A. B. 2000. Tanah-tanah Pertanian di Indonesia: Sumberdaya Lahan Indonesia dan Pengelolaannya. Bogor: Pusat Penelitian Tanah dan Agroklimat. 266p.

Subandi, M. N., Purnama, & Frasetya, B. 2015. Pengaruh berbagai nilai EC (electrical conductivity) terhadap pertumbuhan dan hasil bayam (*Amaranthus* sp.) pada hidroponik sistem rakit apung (floating hydroponics system). Jurnal Agroekoteknologi. 9 (2): 48-56.

Subatra, K. 2013. Pengaruh sisa amelioran, pupuk N dan P terhadap ketersediaan N, pertumbuhan dan hasil tanaman padi di musim tanam kedua pada tanah gambut. Jurnal Lahan Suboptimal. 2 (2): 159-169.

Sudirja, R., Joy, B., Yuniarti, A., Sofyan, E. T., & Mulyani, O. 2017. Beberapa sifat kimia tanah Inceptisols dan hasil kedelai (*Glycine max* L.) akibat pemberian bahan amelioran. Soilrens. 15 (2): 198-205. https://doi.org/10.24198/soilrens.v15i2.15766.

Toago P, S., Lapanjang, I. M., & Barus, H. N. 2017. Aplikasi kompos dan *Azotobacter* sp. terhadap pertumbuhan dan produksi tanaman cabai merah (*Capsicum annuum* L.). Agrotekbis. 5 (3): 291-299.

Vikhe, P. S. 2014. Azotobacter species as a natural plant hormone synthesizer. Research Journal of Recent Sciences. 3 (14): 59-63.

Wahyunto, Hikmatullah, Suryani, E., Tafakresnanto, C., Ritung, S., Mulyan., Sukarman, Sutriadi, T., & Nursyamsi, D. 2016. Pedoman Penilaian Kesesuaian Lahan untuk Komoditas Pertanian Strategis Tingkat Semi Detail Skala 1:50.000. Bogor: Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. 37p.