Available online at http://scik.org
Commun. Math. Biol. Neurosci. 2024, 2024:125
https://doi.org/10.28919/cmbn/8913
ISSN: 2052-2541

BIOLOGICAL PLANTING MEDIA AS MARGINAL LAND RESOLUTION WITH LOCAL BIO INTRODUCTION

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Abstract: Soil is a planting material that has various functions in it, its main function has a lot of influence on life and almost all living things on earth. The most significant role is when the soil becomes a cultivation medium for plants, it is required to provide all the needs of plants to live so the role of soil is very crucial. Control of land improvement still needs to be improved through increasing the natural biology of the local location or adding soil amendment microorganisms to build existing ecosystems to improve the quality of the land. The research method uses the Completely Randomized Design (CRD) method where each treatment indicates several compositions of planting media. The treatments are divided into 3, namely treatment A consisting of 20% Coco Fiber, 20% Husk Charcoal, 20% Goat Manure, 20% Agricultural Lime, and 20% Microorganism Colony. Then followed by treatment B which is 20% Coco Fiber, 10% Husk Charcoal, 20% Goat Manure, 20% Agricultural Lime, 30% Microorganism Colony, and finally treatment C which is 20% Coco Fiber, 20% Husk Charcoal, 10% Goat Manure, 10% Agricultural Lime, 40% Microorganisms Colony. Treatment B shows to be the most successful treatment where the results of agronomic

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Received September 19, 2024

observations, nutrient availability, and the availability of microorganisms and their decomposition process provides the most significant results and has a positive impact of approximately 4.6% on agronomic observations, 5.1% on observations of the role of microorganisms, 6.3% on observations of media nutrients, and 4.2% on observations of organic content and pH. Stabilizing the provision of microorganisms with the types of Nitrogen Fixers, Phosphate Solubilizers, Decomposers, and Root Infectors can make the sustainability of decomposition and decomposition rates run well and a comprehensive symbiotic mutualism occurs so that the introduction can be done with this biological planting media.
Keywords: biological; decomposition; marginal land; planting media; reclamation.

2020 AMS Subject Classification: 92D40.

1. INTRODUCTION

Soil is a planting material that has a variety of functions in it, its main function has a lot of influence on life and almost all living things on earth. The most significant role is when the soil becomes a cultivation medium for plants, this role is as a planting medium that is required to provide all the needs of plants to live so the role of soil is very crucial. Today, the decline in soil quality occurs significantly every year, the current decline has reached ± 70% in the parameter of nutrient loss due to a reduction in the population of soil microorganisms due to not being able to adapt to a dynamically changing environment. This decline then has an impact on the soil as a planting medium whose use is most dominant [1].

Global soil degradation can reduce land quality, whereas systemic degradation greatly affects aspects of crop productivity and subsequently affects soil fertility [2], [3], [4]. This systemic decline then results in degradation of soil structure, increased plant disease [5], [6], increased soil erosion, and can even pollute the environment due to the increasingly acidic soil due to the use of excessive chemical fertilizers that significantly affect soil pH [7]. The occurrence of this decline then affects important parts of the soil which can affect many aspects of soil fertility and health, the most important of which is the loss of microorganisms in the soil and then to lose of organic matter as a source of energy for microorganisms. Soil pollution can also have an impact on ecosystems. Radical changes in soil chemistry can occur due to the presence of harmful chemicals even at low doses. These changes can cause changes in the metabolism of endemic microorganisms and anthropods that live in the soil environment. The impact on agriculture is mainly changes in plant metabolism which can eventually lead to a decrease in agricultural yields. This can lead to further impacts on crop conservation in that crops are unable to retain soil layers from erosion. Some of these contaminants have a long half-life and in other cases, derivative chemicals will be formed from the main soil contaminant [8].

Land functions that change due to industrialization can reduce land quality at a certain point, this activity can also have an impact on soil and water pollution where the most dominant soil damage can be seen from the heavy metal content in the soil with several supporting analyses including the observation of organic matter which has a close relationship with microorganisms [9]. Fertile soil itself is categorized as being able to provide sufficient nutrients or can be reserved for plants, where the biggest role is from microorganisms that can symbiotic mutualism with soil and plants that include aspects of fulfillment earlier. These microorganisms are also intended to improve and increase the level of soil fertility in its chemical, physical, and biological aspects [10].

The control of land improvement still needs to be improved through the enhancement of natural biota from the local site or adding soil amendment microorganisms to build on the existing ecosystem to improve the quality of the land, this is expected to maximize significant changes to the land to be cultivated. Independent soil improvement opportunities allow for the improvement of soil quality so that land improvement can be well-established [11]. Self-improvement is intended to increase soil fertility through a repair medium that has been guaranteed how help properties in the soil. The role of this improvement can then help meet the needs of plants in the continuity of metabolism and production so that land use is in the scheme of changes in the soil. Microorganism inoculants can be a new solution in land reclamation that can have a significant impact and then symbiotic well with plants.

2. MATERIAL AND METHOD

The research method uses the Completely Randomized Design (CRD) method where each treatment indicates several compositions of planting media. The mixture of biological planting media is a mixed treatment, where each mixture has been selected based on methods from references that have been carried out and continued with changes in each microorganism and reduction of other essential ingredients. Table 1 shows the treatment parameters. The types of microorganisms used with colonies are Azotobacter sp, Azospirillum sp, Pseudomonas sp, Actinomycetes, Bacillus sp, and biosynthetic fungi with Arbuscular Mycorrhiza type plants.

Table 1. Treatment Parameters

	Treatment A	**Treatment B**	**Treatment C**
Parameters	Coco fiber 20%	Coco fiber 20%	Coco fiber 20%
	20% Husk Charcoal	10% Husk Charcoal	20% Husk Charcoal
	20% Goat Manure	20% Goat Manure	10% Goat Manure
	Agricultural Lime 20%	Agricultural Lime 20%	Agricultural Lime 10%
	Microorganisms Colony 20%	Microorganisms Colony 30%	Microorganisms Colony 40%
Total	100%	100%	100%

Source:[11], [12], [13], [14]

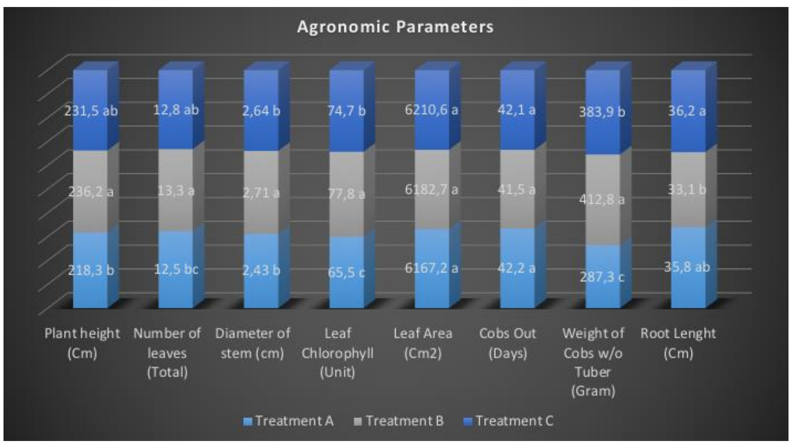
Observations observed by the method are used as a reference for the quality of planting media in bulk form, as for these observations are Total colony count of fungi on media (Total Plate Count); Total colony count of bacteria on media (Total Plate Count); Microbial density in the environment (Biological CFU/mL); Symbiotic activity of worms with microorganisms (Respirometry); Image of the community structure of microorganisms in the media (Microscopic); Total N at environment media; Total P at environment media (Bray & Olsen); Total K at environment media (Spectrophotometry); Carbon Total media (Walkey & Black/Ashing); Organic matter of the media (%); and Average pH of Soil and Media (Units).

Based on the above, the CRD research method is combined with the Panel observation method to determine how the quality of the mixture of materials to see the vegetative to generative growth of plants. The design of the Panel method to evaluate the growth of sweet corn plants as an indicator of fertility in the media. Growth observations include Plant height (Centimeter); Number of leaves (Total); Diameter of stem 10 cm from the ground (Centimeter); Leaf Chlorophyll (Unit); Leaf Area (Square Centimeters); Cobs Out (Days); Weight of Cobs without Tuber (Gram); Root length (Centimeter).

The design of the panel method and the combination of the CRD method determines the behavior of each treatment and estimates how much correlation and the ability of each planting medium for sweet corn plant growth. The experiment used 3 treatment combinations with 10 replicates so that 30 experimental samples were obtained with observations every week on plant experiments and every 2 weeks on planting media experiments during the 75-day planting period of sweet corn plants and data interpretation is presented in the processed data at the end of the study with Duncan's Multiple Range Test (DMRT) at a real level of 5%.

3. MAIN RESULTS

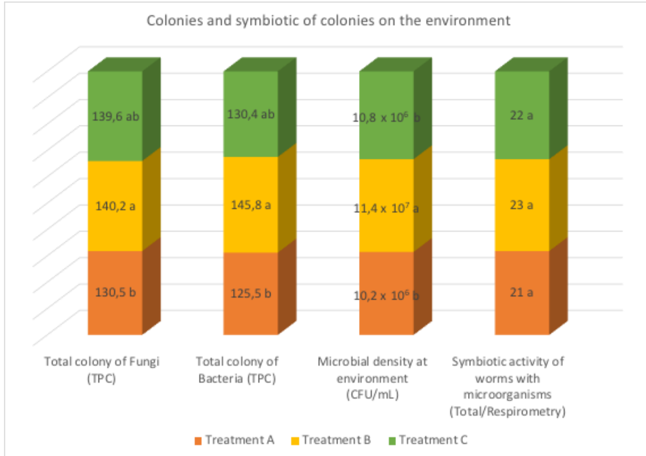
Based on the results of the analysis, the results of Agronomic observations and the results of observations of the quality of planting media are obtained, as the result is shown in Figure 1. Observation parameters There are differences and interactions between planting media treatments carried out, differences and interactions occur in the observation of plant height (cm), number of leaves (strands), stem diameter (cm), chlorophyll (units), cob weight without kelobot (gr), and root length (cm). While the observations that did not interact and were significantly different were in the parameters of leaf area (cm) and cob discharge (days). Based on the observations, treatment B gave the maximum results in the growth of corn plants followed by treatment C and finally treatment A.



*Numbers followed by the same letter in the observation parameters with the same color indicate no significant difference/interaction based on the DMRT test at 5% level.

Figure 1. Results of agronomic analysis during the study period

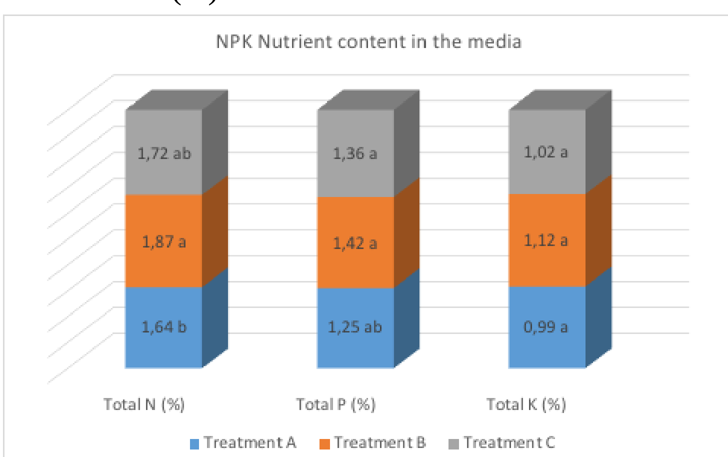
Observation of planting media is an observation of symbiotic mutualism of microorganisms to their environment, as the observation result is shown in Figure 2. Observation parameters There are differences and interactions between treatments and the nature of microorganisms in the growing media, namely the number of fungi per media, the number of bacteria per media, and the total microbial density. While in the treatment of worm symbiosis calculation per media there were no real differences and interactions. Based on the results of the analysis, treatment B gave the maximum results in determining the nature of microorganisms followed by treatment C with moderate results and treatment A with the lowest results.



*Numbers followed by the same letter in the observation parameters with the same color indicate no significant difference/interaction based on the DMRT test at 5% level.

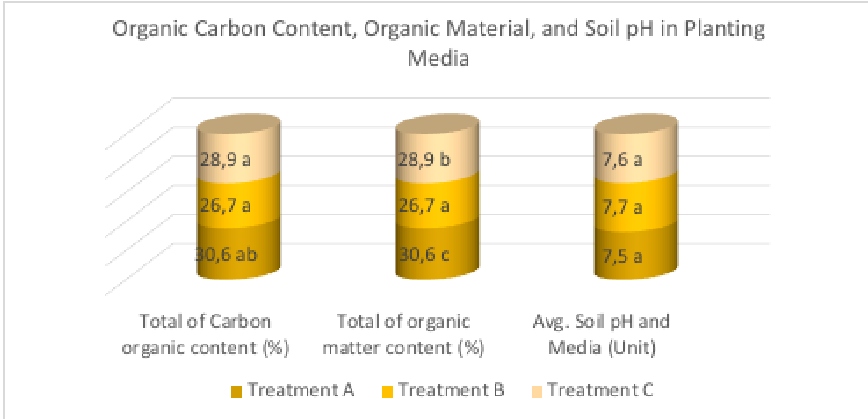
Figure 2. Results of colony analysis and colony characteristics of microorganisms during the study period

Observation of nutrient content parameters shown in Figure 3, there are significant results, these results can be seen from the content of nutrients contained in each planting media, based on the results of observations of Total N and P (%) planting media with treatment B getting the maximum results than treatment A and C. Treatment C gets sufficient results than treatment A. Treatments A, B, and C are not significantly different in the observation parameter of total K (%). Treatment C has better results than treatment A. Treatments A, B, and C are not significantly different in the observation parameter of total K (%).



*Numbers followed by the same letter in the observation parameters with the same color indicate no significant difference/interaction based on the DMRT test at 5% level.

Figure 3. Results of nutrient content analysis of each planting media



*Numbers followed by the same letter in the observation parameters with the same color indicate no significant difference/interaction based on the DMRT test at 5% level.

Figure 4. Results of analysis of organic content and soil pH in planting media

The results of the analysis on the organic content and pH of the media shown in Figure 4 was a fairly comprehensive significance as in the previous treatments and observations where treatment B got the highest results in the content of C-Organic (%) and Organic matter (%) while in the observation parameters of soil and media pH, there was no significant difference in each treatment. Based on the results of these studies and observations, it makes the basis that each planting media treatment provides a continuous effect between the media and the environment around the soil as an organic ameliorant and has the ability and role of organics that can meet the needs of microorganisms introduced into the soil.

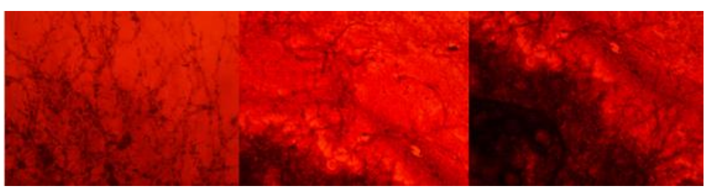


Figure 5. Community structure of microorganisms by microscopic observation in the media and plant root infection

Based on the results of the analysis of the microscopic method, mutualism symbiosis in Figure 5 was established sustainably and causes the important role of microorganisms to take place optimally, in the image of the thread density of microorganism colonies is visible (leftmost and middle images) and the infection between microorganisms and plant root hairs is visible (rightmost image).

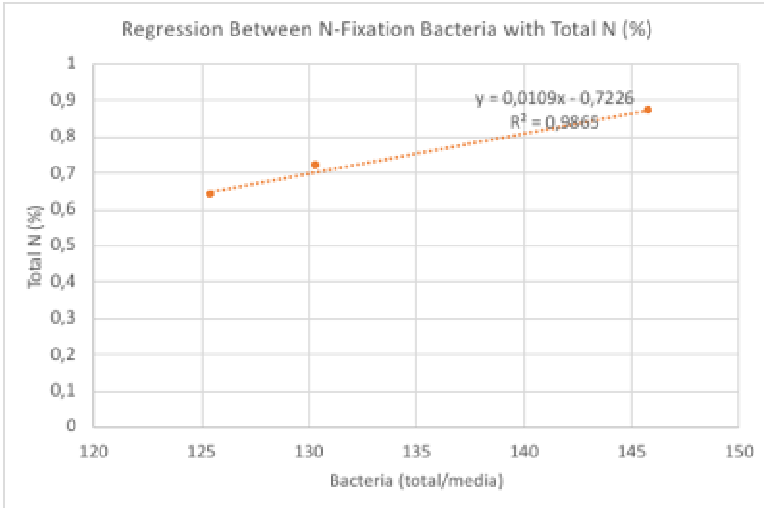


Figure 6. Regression test results between the total number of nitrogen-fixing bacteria and total nitrogen in the media and surroundings

Regression analysis between nitrogen-fixing bacteria and nitrogen availability in Figure 6 has a close relationship, where in this close relationship there is an advanced decomposition process associated with the decomposition process in the biological growing medium and an important role in its availability.

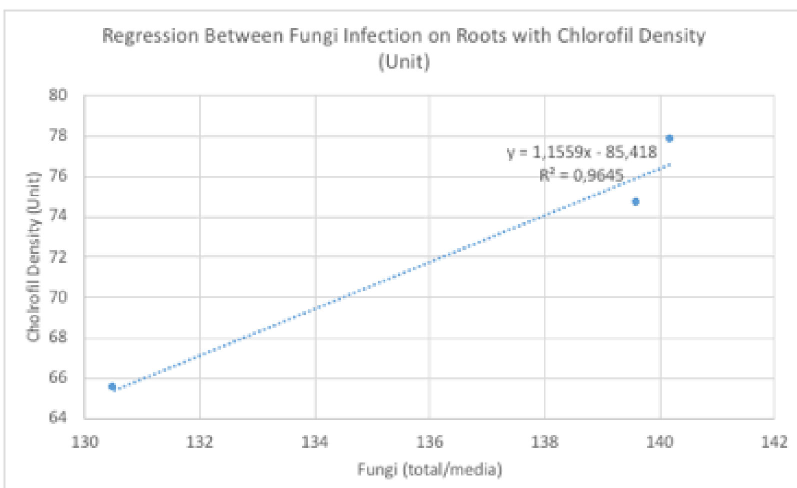


Figure 7. Regression test results between chlorophyll density and the availability of root-infecting microorganisms in the media and its surroundings

Figure 7 shows an analysis of the role of fungal microorganisms makes the basic benchmark in determining the quality of land and good planting media, this determination is clearly stated in the regression test to determine the cause-and-effect in depth to find that in the planting media, there is an infection of plant roots to increase chlorophyll density for plant metabolic processes.

4. DISCUSSION

Planting media is an important formulation in determining the success of plant cultivation, where the main important role is the success in the introduction of microorganisms that can symbiosis with their environment. In this study, the important role of success can be seen from the aspect of corn cultivation treatment that is adjusted to the treatment of planting media. Vegetative and generative growth of maize plants on reclaimed land cannot only place nutrients for plants but also the readiness to decompose nutrients so that they are mineralized into nutrients available to plants [1].

The advanced decomposition process can be used as a reference for success in crop cultivation on problematic or marginal lands where the placement of this process must follow the rules for the placement of supporting microbes to increase the generative phase of the plant. In Figure 1, the influence of planting media is important because vegetative or generative results have a different effect and it is clear that the addition of colonies to the planting media provides additional yields above the average corn plant. The addition of microorganisms per 10% gives quite high results in each treatment. This treatment also affects the vegetative phase where plant height, number of leaves, stem diameter, chlorophyll, cob weight, and root length require amino acids continuously and continuously [1], [15]. In the treatment of leaf area and cob exit, it is not significantly different, this is because the decomposition function in the planting media used has been running properly and has become protein synthesis and nutrient availability has been fulfilled [1], [16].

Planting media variables on colony parameters and colony properties of microorganisms (Figure 2) have different symbiotic processes. The ideal number of microorganisms consists of 30 to 300 colonies when counted and has an ideal value between 100 to 150 colonies with the Total Plate Count (TPC) method [9], [17]. In this study, there was an average of 136.7 colonies in fungi-type microorganisms and 133.9 colonies in bacterial-type microorganisms, based on this, the bio-introduction of planting media was classified as successful and had an average of 10.8 x 107 microorganism density which is likely to increase this density will provide the most significant results in determining the decomposition of the media and the average number of worms from the media given to be an advantage for the surrounding environment in the application of biological planting media [18], [19], [20].

Objectivity in the treatment of biological planting media in addition to the addition of microorganisms will also be fulfilled if the chemical fertility aspects of the planting media and surrounding soil increase significantly. The allotment of organic matter decomposition will increase the nutrient content of Nitrogen, Phosphate, and Potassium in the press planting media [9]. The nutrient quality obtained is total Nitrogen with an average of 1.74%, total Phosphate with an average of 1.34%, and total Potassium with an average of 1.04%. This is a benchmark for the success of decomposition on the parameters of NPK nutrient content that follows the standard and is believed to increase its availability based on a longer research time.

The handling of the decomposition rate contained in the planting media follows the rules of calculation between the C/N ratio of the resulting media, by the release of nutrients and the important role of microorganisms, the decomposition rate is still considered to be fulfilled over time and following the composition of each plant media. The C/N ratio resulting from the planting media is treatment A 18.65%, treatment B 14.27%, and treatment C 16.80% where the standard C/N should indicate that advanced decomposition has occurred and there is a change in the form of description in the planting media so that the possibility of adding nutrients and organic matter will fluctuate greatly with environmental changes and the introduction of local biology [1], [13], [21]. While the pH of the soil and media has an average of 7.6 where in this aspect the availability of pH tends to be neutral to slightly alkaline.

The results of regression testing indicate that in addition to decomposition, there is also an increase in total Nitrogen (%) and an increase in chlorophyll density based on the specifications of microorganisms and the total number of microorganisms contained in the growing media. In Figure 6 there is an increase in Nitrogen-fixing microorganisms by looking at the addition of Total Nitrogen in the media and the environment. Research conducted by Guo et al. [22] stated that any decomposition of Nitrogen must be in line with the addition of total Nitrogen levels in the soil, so it can be used as a definite parameter and become amino acid synthesis in the planting media material. Then, in the research treatment, the Regression results on Total N and its Fixation from microorganisms have a close relationship of 0.9865 which supports the fixation decomposition and mineralization of Nitrogen in the growing media and growing media environment.

The regression between chlorophyll density and the availability of root-infecting microorganisms (Figure 7) is also clearly visible with value of 0.9645, indicating a close relationship between the two. This is also the case in research conducted by Pan et al. [23] and Levesque et al. [24] where the intertwining of the decomposition process is related to the infection of plant roots by soil-improving microorganisms in the form of Arbuscular Mycorrhiza and has a positive effect, namely increasing chlorophyll density and optimizing photosynthetic processes for plants. The observation of community structure is also in line with the explanation above, where each biological planting media treatment and its introduction supports the surrounding environment to be able to have a positive impact, and further decomposition processes and decomposition rates occur in line with the release of nutrients and an increase in the generative and vegetative phases of experimental plants.

Thus this biological planting media can be used as a planting media that can be used on critical or marginal lands and can be implemented directly on a massive scale if needed. Based on the results of the research, the independence of microorganism introduction through biological planting media can be increased due to the balance between the organic material used and the type of microorganism given. This role then provides a definite input to the determination of the fertility of the surrounding soil due to gradual soil improvement.

5. CONCLUSIONS

The role of planting media is important in the aspect of plant cultivation, where the importance of planting media follows the obligation to provide plant needs and important things in its application in the field. Based on the results of the study, treatment B has proven to be the most successful treatment where the results of agronomic observations, nutrient availability, and the availability of microorganisms and their decomposition process gave the most significant results and had positive impact of approximately 4.6% on agronomic observations, 5.1% on observations of the role of microorganisms, 6.3% on observations of media nutrients, and 4.2% on observations of organic content and pH in the media compared to other treatments. In this case, stabilizing the provision of microorganisms with the types of Nitrogen Fixers, Phosphate Solubilizers, Decomposers, and Root Infectors can make the sustainability of decomposition and decomposition rates run well and a comprehensive symbiotic mutualism occurs.

ACKNOWLEDGMENT

The author(s) extends heartfelt gratitude to Directorate of Research, Technology, and Community Service; the Directorate General of Higher Education, Research, and Technology; and the Ministry of Education, Culture, Research, and Technology of Republic of Indonesia for providing funding for this research under Fundamental Research scheme in 2024 (Contract No. 107/E5/PG.02.00.PL/2024 and 0609.25/LL5-INT/AL.04/2024, 001/KS/LPPM/VI/2024).

Data supporting this multiyear study cannot be made available due to the study is still on going.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

REFERENCES

[1] D.P. Putra, M.P. Bimantio, A.A. Sahfitra, et al. Simulation of availability and loss of nutrient elements in land with Android-based fertilizing applications, in: 2020 International Conference on Information Management and Technology (ICIMTech), IEEE, Bandung, Indonesia, 2020: pp. 312–317. https://doi.org/10.1109/ICIMTech50083.2020.9211268.

[2] H. Soeparno, A.S. Perbangsa, B. Pardamean, Best practices of agricultural information system in the context of knowledge and innovation, in: 2018 International Conference on Information Management and Technology (ICIMTech), IEEE, Jakarta, 2018: pp. 489–494. https://doi.org/10.1109/ICIMTech.2018.8528187.

[3] J. Baurley, A. Perbangsa, A. Subagyo, et al. A web application and database for agriculture genetic diversity and association studies, Int. J. Bio-Sci. Bio-Technol. 5 (2013), 33–42. https://doi.org/10.14257/ijbsbt.2013.5.6.04.

[4] J.W. Baurley, A. Budiarto, M.F. Kacamarga, et al. A web portal for rice crop improvements, Int. J. Web Portals 10 (2018), 15–31. https://doi.org/10.4018/IJWP.2018070102.

[5] T. Suparyanto, E. Firmansyah, T.W. Cenggoro, et al. Detecting hemileia vastatrix using vision AI as supporting to food security for smallholder coffee commodities, IOP Conf. Ser.: Earth Environ. Sci. 998 (2022), 012044. https://doi.org/10.1088/1755-1315/998/1/012044.

[6] Hermantoro, M.A. Kurniawan, J.P. Trinugroho, et al. Detecting Ganoderma basal stem rot disease on oil palm using artificial neural network method, Commun. Math. Biol. Neurosci. 2023 (2023), 40. https://doi.org/10.28919/cmbn/7911.

[7] N.R. Zani, Design and development of soil nutrients level detection system based on soil color and pH for crop recommendations using fuzzy algorithms, Indones. Green Technol. J. 11 (2022), 38-45. https://doi.org/10.21776/ub.igtj.2022.011.01.05.

[8] S. Wahyuni, S. Kadarwati, R. Aprilia, Biofertilizer berbasis biochar untuk remediasi lahan pertanian Indonesia, Bookchapter Alam Univ. Negeri Semarang 2 (2023), 145–177. https://doi.org/10.15294/ka.v1i2.140.

[9] P. Oktavian, M. Anas, I.N. Sudiana, et al. Literature review study: The effect of the presence of heavy metals

on soil fertility levels in Indonesia, Einsteins Res. J. Appl. Phys. 2 (2024), 1.

[10] R.A. Streletskii, A.A. Astaykina, A.A. Belov, et al. Beneficial soil microorganisms and their role in sustainable agriculture, in: Sustainable Agricultural Practices, Elsevier, 2024: pp. 293–333. https://doi.org/10.1016/B978-0-443-19150-3.00013-8.

[11] D.P.P. Suwarno, N.S. Nugraha, B. Yuniasih, et al. Expert program for determining soil health using backward chaining method based on landsat normalized difference vegetation index, J. Pengelolaan Perkeb. 4 (2023), 2.

[12] D.P. Putra, P. Bimantio, T. Suparyanto, et al. Expert system for oil palm leaves deficiency to support precision agriculture, in: 2021 International Conference on Information Management and Technology (ICIMTech), IEEE, Jakarta, Indonesia, 2021: pp. 33–36. https://doi.org/10.1109/ICIMTech53080.2021.9535083.

[13] T.W. Cenggoro, F. Tanzil, A.H. Aslamiah, et al. Crowdsourcing annotation system of object counting dataset for deep learning algorithm, IOP Conf. Ser.: Earth Environ. Sci. 195 (2018), 012063. https://doi.org/10.1088/1755-1315/195/1/012063.

[14] M.T. Hafizal, D.P. Putra, H. Wirianata, et al. Implementation of expert systems in potassium deficiency in cocoa plants using forward chaining method, Procedia Computer Sci. 216 (2023), 136–143. https://doi.org/10.1016/j.procs.2022.12.120.

[15] E.R. Setyawati, D.P. Putra, M. Rinaldy, Effect of planting media composition and consentration of vegetable waste liquid organic fertilizer on the growth of oil palm seedlings (elaeis guineensis jacq) in the main nursery, Int. J. Life Sci. Agric. Res. 03 (2024), 375–381. https://doi.org/10.55677/ijlsar/V03I5Y2024-07.

[16] E. Firmansyah, B. Pardamean, C. Ginting, et al. Development of artificial intelligence for variable rate application based oil palm fertilization recommendation system, in: 2021 International Conference on Information Management and Technology (ICIMTech), IEEE, Jakarta, Indonesia, 2021: pp. 6–11. https://doi.org/10.1109/ICIMTech53080.2021.9535082.

[17] R.E. Caraka, N.T. Nugroho, S.K. Tai, et al. Feature importance of the aortic anatomy on endovascular aneurysm repair (EVAR) using Boruta and Bayesian MCMC, Commun. Math. Biol. Neurosci. 2020 (2020), 22. https://doi.org/10.28919/cmbn/4584.

[18] W. Hidayat, R.M. Hartati, D.P. Putra, Providing P fertilizer and empty oil palm bunches compost as a planting media mix effect on the growth of mucuna bracteata, Agroforetech, 2 (2024), 2.

[19] D.P. Putra, N.S. Nugraha, T. Suparyanto, et al. Ekonomi sirkular lokal: pemanfaatan limbah organik pasar menjadi pupuk organik cair dan pupuk kompos di pasar cokro, desa daleman, kecamatan tulung, kabupaten klaten, J-Dinamika: J. Pengabdi. Masy. 9 (2024), 284-288.

[20] D.P.P. Suwarno, Technosol tanah masa depan, AGROISTA J. Agroteknol. 02 (2018), 93-107

[21] P.T. Duong, P.C. Nhung, Assessment of the concentration of some heavy metals in bottom sediments in the

coastal and island areas of the southern region, Vietnam, J. Degraded Mining Lands Manage. 11 (2024), 6071–6079. https://doi.org/10.15243/jdmlm.2024.114.6071.

[22] Z. Guo, W. Qiang, J. He, et al. Nitrogen deposition raises temperature sensitivity of soil organic matter decomposition in subtropical forest, Sci. Total Environ. 907 (2024), 167925. https://doi.org/10.1016/j.scitotenv.2023.167925.

[23] Y. Pan, L. Meng, Y. Wu, et al. Molecular composition limits the reaction kinetics of riverine dissolved organic matter decomposition, Sci. Total Environ. 950 (2024), 175454. https://doi.org/10.1016/j.scitotenv.2024.175454.

[24] D. Lévesque, M. Lebeuf, M. Starr, Using chlorophyllic organic matter degradation in the deep St. Lawrence Estuary as an indicator of water column remineralization, Front. Mar. Sci. 11 (2024), 1399961. https://doi.org/10.3389/fmars.2024.1399961.