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Original Paper

Application of Rhizobacteria to Control *Phytophthora capsici* Disease Causes Stem Base Rot and Increase Growth of Pepper Seedlings In-Vivo

La Mudi[1], Zainal Abidin[1], Riama Rita Manullang[1], Sopian Agus[1], Helmi Ahmad Gyn'nandi[1], Tasya Valentina Putri[1], Gusti Ayu Kade Sutariati[2]*

1) *State Agricultural Polytechnic of Samarinda, Samarinda, 75131, Indonesia*
2) *Department of Agrotechnology, University of Halu Oleo, Kendari, 93231, Indonesia*

*) *Corresponding Author: lamudi89@gmail.com*

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***Abstract*— One obstacle to pepper production is the high intensity of plant disease attacks. One of these is stem rot disease caused by the fungus *Phytophthora capsici*. Therefore, appropriate technology is needed to control disease and simultaneously increase plant growth by using rhizobacteria that are environmentally friendly and can produce growth hormones, dissolve phosphate, and fix nitrogen. This study aimed to obtain rhizobacterial isolates that can control the pathogen *P. capsici*, which causes root rot disease, while also increasing plant growth. This study was conducted at the Agronomy Laboratory of the Plant Cultivation Study Program, Samarinda State Agricultural Polytechnic. The study used a completely randomized design consisting of four treatments with four replicates to obtain 16 experimental units. The variables observed included the latent period, disease incidence and severity, increase in plant height, number of leaves, and stem diameter. The resulting data were analyzed using analysis of variance (ANOVA). The results of the analysis showing a real effect were followed by the Least Significant Difference test (BNT)$_{\alpha=0.05}$. The results of this study showed that the application of a combination of rhizobacteria was able to overcome stem rot disease and simultaneously increase the growth of pepper plant seedlings. The combination of rhizobacteria isolate P01 + TA2 treatment can reduce the latent period of disease to 12.00 days compared to 5.50 days without rhizobacteria, the disease incidence rate was 6.25% with a severity level of 2.50%, lower than of treatment (control) at 37.50 % (disease incidence) and 47.50% (disease severity). In addition, the combination of rhizobacterial isolates P01 + TA2 was able to increase the growth of pepper plant seeds, as shown by the increase in plant height, number of leaves, and stem diameter.**

Keywords*—Rhizobacteria combination, disease incidence, P. capsici, latent period.

I. Introduction

Pepper is a traditional commodity in East Kalimantan (Kaltim) and has been widely developed because it is an export crop. Pepper in East Kalimantan is widely developed in Loa Janan, Muara Badak, Kutai Kartanegara District, Sepaku District, North Penajam Paser District, and Berau District [1]. Pepper contains 3.13% - 4.46% essential oil, and 5.25% - 6.63% piperine [2]. Pepper production in 2019 was 5,799 tons, and the demand for pepper increased every year [1]. However, pepper production has decreased due to high rainfall, and many pepper plants are attacked by stem rot.

Stem rot disease is caused by the fungus *Phytophthora capsici*. The losses caused start from seeding until just before the harvest. The intensities of *P. capsici* attacks reached 14.58% [3], 55.66% [4], and 61.2% [5]. *P. capsici* is a soilborne disease microbe and can survive on infected plant parts. In addition, the spread of stem rot disease can begin in nurseries. It has been reported that the development of pathogens through seeds/cuttings can transmit stem rot disease [4].

Therefore, disease control techniques using rhizobacterial inoculations are required. Rhizobacteria are beneficial microbes in the rhizosphere of plants that can act as biofertilizers and bioprotectants [6]. Microbes can suppress the growth of *P. capsici* [7]. It was further reported that the use of biological agents could reduce the incidence of disease by up to 54-76% [8]. Furthermore, the use of microbes can also act as a bioprotectant to control *P. capsici*, *P. infestans*, and *P. nicotianae* diseases [9].

The use of rhizobacteria alone is quite effective in controlling disease [10-11] and can also increase plant growth [12]. Based on the advantages of rhizobacteria alone, it is hoped that the combined application of rhizobacteria can provide significant results in increasing plant resistance to disease and plant growth. The combination of endophytic microbes and rhizobacteria can increase salicylic acid production and peroxidase enzyme activity in plants, which can reduce the incidence and severity of blast disease when compared to controls [13]. The application of salicylic acid is more resistant to *P. capsici* [14]. The use of a consortium of biological agents can reduce the incidence of *P. capsici* and *Colletotrichum* sp., while also increasing the growth and yield of paprika plants [15]. Furthermore, it has been reported that a mixture of rhizobacteria can increase plant yields [12]. Research related to rhizobacteria single is reported to be effective in controlling growth and pepper diseases. However, the combination of rhizobacteria for growth and disease control in pepper plants has not yet been widely reported.

The specific aim of this study was to obtain rhizobacterial isolates that can control the *P. capsici* pathogen that causes stem base rot, while also increasing the growth of pepper plant seedlings.

II. Material and Methods

A. Description of Study Area

This study was conducted at the Agronomy Laboratory of the Plant Cultivation Study Program. Pathogen samples were obtained from community gardens in Batuah Village, Samboja District. This study was conducted between July and September 2023.

B. Experimental Material

Rhizobacteria have been isolated from the rhizosphere of palm oil plants [16]. Pepper seeds were obtained from Samboja District, Batuah Village.

C. Experimental Design

An experimental design is used in this study. The study was structured using a completely randomized design consisting of four treatments with four replications to obtain 16 experimental units. Each experimental unit consisted of four polybags, resulting in 64 experimental polybags. Details of the rhizobacteria application treatment are presented in TABLE I.

TABLE I. Detail of rhizobacteria application treatments

Treatments	***Treatment Details***
A0	Without rhizobacteria (control)
A1	Rhizobacteria isolate P01
A2	Rhizobacteria isolate TA2
A3	Rhizobacteria isolates P01 + TA2

D. Method

Phase 1 of the experiment began by collecting the *P. capsici* pathogen from sick pepper plants (plant roots). The plant roots were then transported to the laboratory. The surfaces of the plant roots were then cleaned using 5% NaOCl for 3 min, followed by 70% alcohol for 3 min, and rinsed with sterile distilled water three times. The root samples were then cut horizontally into small pieces and grown in solid Vjuice medium. The V juice is made by weighing tomatoes, carrots, pears, green spinach, celery leaves, baby corn, and bean sprouts (mashed by blending in 200 ml water and then filtering). The extract is then centrifuged at rpm speed, then the supernatant is taken and mixed with 20 g of agar and 5 g of $CaCO_3$ (boiled until boiling on a hot plate and sterilized in an autoclave at 121ºC, 2 atm pressure for 15 minutes and then poured into a petri dish with a thickness of 0,5 ml aseptically in a Laminar Air Flow Cabinet (LAFC). The pathogen that grew was then purified and observed under a microscope and characterized to confirm the test pathogen. Next, the pathogen was multiplied for 7 days, suspended in sterile distilled water (1 Petri dish of 50 ml), and shaken for 24 h at a speed of 150 rpm. Next, the pathogen was applied to the plants (15 ml per plant). Rhizobacterial isolates were grown on solid Tryptic Soy Agar media (30 g Tryptic Soy Broth + 20 g agar + 1 l distilled water boiled until boiling and sterilized in an autoclave at 121oC, pressure 2 atm for 15 minutes and then poured into a petri dish with a thickness of 0.5 ml aseptically in the LAFC). The rhizobacteria were then incubated for 24 h, a suspension was made (1 Petri dish of 50 ml of sterile distilled water), and then shaken for 24 h at a speed of 150 rpm. The application of rhizobacteria was carried out according to the treatment, namely 15 ml of rhizobacterial suspension (for single application) and 30 ml (for combination application of rhizobacteria). The rhizobacterial application was carried out first, followed by pathogen application 5 days after rhizobacterial application. Rhizobacteria were applied 2 times, namely 7 days and 30 days after moving the plants.

E. Observations

The variables observed in the study included the latent period of the disease, disease incidence [17], disease severity [18], increase in plant height, number of leaves, and stem diameter of pepper seedlings. The disease resistance test formula is as follows:

$$Ii = \sum(\frac{ni}{Ni})\ x\ 100\% \qquad (1)$$

Where *li*= incidence of diseased seedlings; *ni*= number of diseased seedlings at time *i*; and *Ni*= total population of inoculated seedlings.

$$DS = \sum\frac{(ni\ x\ vi)}{(N\ x\ Z)}\ x\ 100\% \qquad (2)$$

Where DS = disease severity; y = number of infected plants; N = number of plants observed; ni = number of diseased plant parts with a certain score; v = numeric scale (score); Z = highest score

F. Data Analysis

The observation data were analyzed using analysis of variance. The analysis results showing a real effect were followed by the Least Significant Difference test (BNT)α=0.05. Data were analyzed using the STAR (Statistical Tool for Agricultural Research) program version 2.0.1.

III. Results and discussion

Research on the application of rhizobacteria has shown that it has a significant effect on controlling disease and increasing the growth of pepper seedlings.

A. Control of *P. capsici* disease

The results of the research on latent period observations are presented in Figure 1, while disease incidence and disease severity are presented in Figure 2.

The results in Figure 1 show that the fastest latent period for *P. capsici* pathogen infection was obtained without treatment for 5.50 days. In a single treatment with rhizobacteria, the latent period for pathogen infection reached 8.50 days (isolate P01) and 7.50 days (isolate TA2). The latent period of pathogen infection in the combination treatment of rhizobacterial isolates P01 and TA2 reached 12 days. This ability is thought to be caused by the ability of rhizobacteria to compete with pathogens to obtain nutrients and living space, so that pathogens will be slow to develop [19]. In addition, the ability of rhizobacteria to produce antimicrobial compounds can increase plant resistance to pathogens [20-21]. In this study, the dual use of biological agents was more effective in controlling pathogens due to the dual ability of rhizobacteria. This is in line with research reporting that microbial consortia can increase plant resistance to pathogens [11, 22].

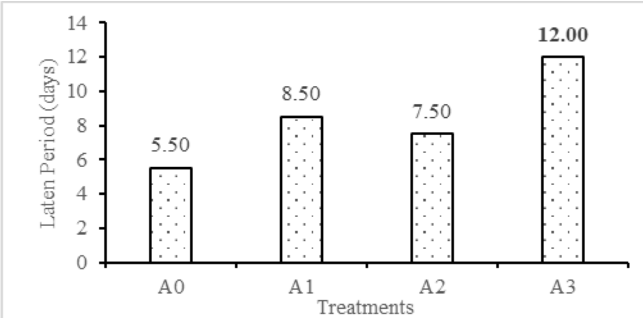

Fig. 1. Latent period of *P. capsici* disease in various rhizobacteria treatments

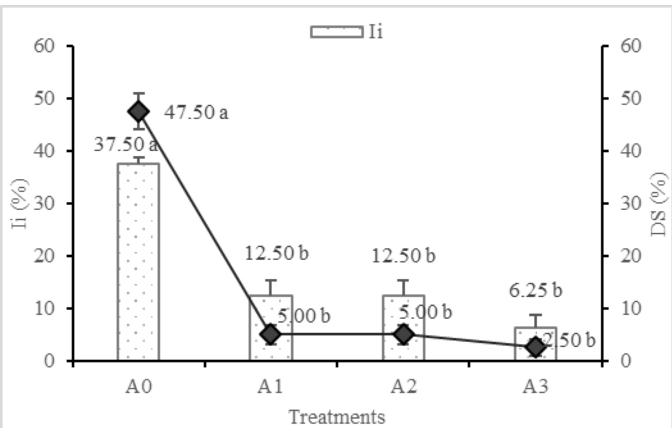

Fig. 2. Occurrence and severity. Note: Numbers followed by the same letter in the image are not significantly different in the BNTα=0.05 test.

The results in Figure 2 show that rhizobacterial treatment had the highest incidence of disease without treatment (control) at 37.50% with a disease severity level of 47.50%, which was significantly different from rhizobacterial treatment either alone or in combination with rhizobacterial treatment. The lowest disease incidence was observed in the treatment with the combination of rhizobacterial isolates P01 + TA2 at 6.25%, with a disease severity level of 2.50%. This shows that the use of rhizobacteria, whether using single isolates or combinations of rhizobacteria, can control *P. capsici*, which causes stem base rot in pepper plants.

Seed bio-priming treatment increases the resistance of local cayenne pepper plants [23]. Bio-priming seeds with biological agents can also increase plant resistance to pathogens [243]. Other studies have reported that a combination of microbes can suppress the incidence of disease [25-26]. The combined application of *B. subtilis* and P. fluorescens increased plant resistance to the pathogen *R. solanacearum* by up to 44.75% and 67.30%, respectively, compared to the control [27]. The consortium of biological agents was able to suppress *P. colocasiae* disease in the greenhouse by up to 88.75-99.37%. [28]. Other studies have also reported that the combination of rhizobacteria and mycorrhiza can increase the absorption of soil nutrients, which play a role in plant growth, infection of root pathogens, and increased plant resistance to drought [29].

B. The Growth of pepper seedlings

The results of the research on the increase in plant height, number of leaves, and stem diameter of pepper seedlings are presented in TABLE II, III, and IV, respectively.

TABLE II. INCREASING HEIGHT OF PEPPER PLANT WITH RHIZOBACTERIA TREATMENTS

Treatments	***Plant Height (cm)***			
	2 WAP	***4 WAP***	***6 WAP***	***8 WAP***
A0	5.78 ±1.05 ^{c}	7.61 ±1.32^{c}	9.59 ±1.69^{c}	11.46 ±2.23^{c}
A1	8.40 ±0.00 ^{ab}	12.23 ±0.20^{b}	14.43 ±1.71^{b}	16.25 ±2.99^{b}
A2	7.88 ±1.05^{b}	12.23 ±1.19^{b}	14.71 ±0.89^{b}	16.76 ±1.40^{b}
A3	9.50 ±0.90^{a}	15.96 ±1.82^{a}	21.99 ±2.22^{a}	26.76 ±3.02^{a}

Note: Numbers followed by the same letter in different columns are not significant in the BNTα=0.05 test (±SE)

The results in TABLE II regarding the highest increase in plant height at an observation age of 2 MSP were obtained in the combination treatment of rhizobacteria isolate P01 + TA2 (9.50 cm which was not significantly different from the single treatment of isolate P01 (8.40 cm but was significantly different from the single treatment at isolate TA2 (7.88 cm, especially without rhizobacteria treatment, it was 5.78 cm. The results of the study on the highest increase in plant height at the ages of 4, 6, and 8 WAP were obtained in the combination treatment of rhizobacteria isolate P01 + TA2, which was significantly different from other treatments, especially without rhizobacterial treatment (control). The use of rhizobacteria, either single or in combination, can increase plant height. increase in the number of pepper plant leaves in the rhizobacterial treatments.

TABLE III. INCREASING THE NUMBER OF PEPPER LEAVES IN RHIZOBACTERIA TREATMENTS

Treatments	***Number of Leaves (Strands)***			
	2 WAP	***4 WAP***	***6 WAP***	***8 WAP***
A0	1.38 ±0.25 ^{c}	3.25 ±0.65 ^{c}	4.25 ±0.50 ^{c}	5.13 ±0.48^{c}
A1	2.00 ±0.00^{b}	4.13 ±0.48^{b}	5.50 ±0.41^{ab}	6.50 ±0.91^{b}
A2	1.88 ±0.25^{b}	3.75 ±0.65^{bc}	5.13 ±0.48^{b}	6.25 ±0.50^{bc}
A3	2.50 ±0.41^{a}	5.00 ±0.41^{a}	6.13 ±0.48^{a}	8.75 ±0.96^{a}

Note: Numbers followed by the same letter in different columns are not significant in the BNTα=0.05 test (±SE)

The results of the research in TABLE III show that rhizobacterial treatment using rhizobacteria isolates increased the number of leaves of pepper plants at the ages of 2, 4, and 6 WAP obtained in the combination treatment of rhizobacteria isolates P01 + TA2, which was not significantly different from the single rhizobacteria treatment, but was different. real without treatment. Meanwhile, at the observation age of 6 WAP, the highest number of leaves was obtained in the P01 + TA2 isolate treatment which was not significantly different from the P01 isolate but was significantly different from the other treatments, especially when compared with no treatment.

The results in TABLE IV show that the stem diameter increased with each observation time. The highest treatment was obtained in the P01 + TA2 treatment, which was not significantly different from the TA2 isolate and the P01 isolate at the observation ages of 4 and 6 WAP, but was different from that without treatment. Meanwhile, the highest observation results for stem diameter at the observation age of 8 WAP were obtained in the P01 + TA2 isolate treatment, which was not significantly different from the TA2 isolate treatment but was significantly different from other treatments, especially without treatment.

TABLE IV. INCREASE IN STEM DIAMETER OF PEPPER PLANTS IN RHIZOBACTERIA TREATMENTS

Treatments	***Stem Diameter (cm)***			
	2 WAP	***4 WAP***	***6 WAP***	***8 WAP***
A0	0.053 ±0.009	0.100 ±0.008 [b]	0.127 ±0.009 [b]	0.200 ±0.013 [c]
A1	0.070 ±0.025	0.116 ±0.024[ab]	0.142 ±0.023[ab]	0.218 ±0.026[bc]
A2	0.079 ±0.005	0.126 ±0.004[a]	0.156 ±0.005[a]	0.236 ±0.011[ab]
A3	0.084 ±0.003	0.133 ±0.006[a]	0.159 ±0.005[a]	0.244 ±0.017[a]

Note: Numbers followed by the same letter in different columns are not significant in the BNTα=0.05 test (±SE)

The increase in plant growth is caused by the ability of rhizobacterial isolates to produce growth hormones in the form of IAA, dissolve phosphate, and fix nitrogen [30]. The research results in TABLE I, II, and III show that the rhizobacteria combination treatment gave the best results when compared with other treatments, especially the controls. This is due to the ability of rhizobacteria to produce growth hormones in the form of IAA, dissolve phosphate, and fix nitrogen [30], which, when combined, can have a double effect on increasing the growth of plant height, number, and diameter of pepper plant stems. This is in line with previous research, which reported that a mixture of rhizobacterial isolates PKLK7 + *Bacillus* sp. CKD0061 increased the growth of peanut plants [12]. A combination of biological agents was also reported to increase the IAA concentration in tobacco roots [31].

by the ability of rhizobacteria to solubilize phosphate [32]. Phosphate nutrients can store and transfer energy in plants [33]. Phosphorus also plays an important role in photosynthesis, carbohydrate metabolism, nucleus formation, cell division, and multiplication [34]. This can increase the plant growth [35]. Apart from that, rhizobacteria are also reported to be able to fix nitrogen. Nutrient N functions as a building block for proteins, chlorophyll, amino acids, and many other organic compounds, and the functions and roles of most of these compounds support and complement each other [36-37]. It was further reported that rhizobacteria can produce IAA. IAA synthesis by PGPR influences cell division, cell enlargement, phototropism, root initiation, growth rate, apical dominance, and geotropism in plants [38].

Application of rhizobacteria has been reported to increase plant growth [39-40]. It was further reported that the application of a combination of rhizobacteria increased the growth of chili plants and chili plant production by 90 % when compared to the control [41]. Application of the endophytic bacterial consortium *Bacillus* sp. SJI + *S. marcescens* JB1E3 increased plant height growth by up to 38% and increased the number of chili leaves by 70% compared to the control [42].

IV. CONCLUSION

The application of a combination of rhizobacteria can overcome stem rot disease and increase the growth of pepper seeds. The combination treatment of rhizobacteria isolates P01 + TA2 suppresses the latent period of disease for 12.00 days when compared without rhizobacteria (control) for 5.50 days, the disease incidence rate is 6.25% with a severity level of 2.50%, with lower when compared without treatment (control) by 37.50% (disease incidence) and 47.50% (disease severity). In addition, it can also increase the growth of pepper plant seeds, as shown by the increase in plant height, number of leaves, and stem diameter.

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CONFLICT OF INTEREST

We state that there are no conflicts of interest for this experiment.

REFERENCES

[1] Disbun Kalimantan Timur. (2020). Lada, disbun.kaltimprov, 26 November 2021. https://disbun.kaltimprov.go.id/artikel/lada.

[2] E. Sampepana, A. Rinaldi, T. Nurwidayati, S.H. "Kadar air, piperin dan minyak atsiri lada produk ukm Samboja, UKM Bontang dan di pasaran Samarinda". Jurnal Riset Teknologi Industri. 14(2): 275-283. 2020.

[3] N. Akhsan, A. Patangke. "Intensitas Penyakit Busuk Pangkal Batang Pada Tanaman Lada (*Piper nigrum* L) Di Desa Batuah Kecamatan Loa Janan Kabupaten Kutai Kartanegara". *Agrifarm: Jurnal Ilmu Pertanian*, 8(2), 51–56. 2022. https://doi.org/10.24903/ajip.v8i2.852

[4] Asniah, Syair, T.A.S. Wahyuni. "Survei Kejadian Penyakit Busuk Pangkal Batang (*Phytophthora capsici*) Tanaman Lada (*Piper nigrum* L.) di Kabupaten Konawe Selatan. *J. Agroteknos, 2*(3), 151 – 157. 2012.

[5] L.O.S. Bande, B. Hadisutrisno, S. Somowiyarjo, B.H. Sunarminto. "Karakteristik *Phytophthora capsici* Isolat Sulawesi Tenggara". *Agriplus, 21* (1), 75 – 82. 2011.

[6] P. Raval, J.R. Patel, N. Chaundary, M. Joshi. "Role of Plant Growth Promoting Rhizobacteria (PGPR) in Sustainable Agriculture". *The Pharma Innovation Journal, 12*(3): 3225-3231. 2023.

[7] Y. Fitriana, D.A.T. Tampubolon, R. Suharjo, P. Lestari, I.G. Swibawa. "*Lysinabacillus fusiformis* and *Paenibacillus alvei* Obtained from the Internal of Nasutitermes Termites Revealed Their Ability as Antagonist of Plant Pathogenic Fungi". *Plant Pathol. J. 38*(5): 449-460 (2022) https://doi.org/10.5423/PPJ.OA.03.2022.003.

[8] M. Santos, F. Diánez, B. Sánchez-Montesinos, V. Huertas, A. Moreno-Gavira, B. Esteban-García, J.A. Garrido-Cárdenas, F.J. Gea. "Biocontrol of Diseases Caused by *Phytophthora capsici* and *P. parasitica* in Pepper Plants". *J. Fungi, 9*, 360. https://doi.org/10.3390/jof9030360. 2023.

[9] E. Volynchikova, K.D. Kim. "Biological Control of Oomycete Soilborne Diseases Caused by *Phytophthora capsici, Phytophthora infestans*, and *Phytophthora nicotianae* in Solanaceous Crops". *Mycobiology. 50*:5, 269-293, DOI: 10.1080/12298093.2022.2136333. 2022.

[10] K.S. Wijayanti, B.T. Rahardjo, T. Himawan. "Pengaruh Rizobakteri dalam Meningkatkan Kandungan Asam Salisilat dan Total Fenol Tanaman Terhadap Penekanan Nematoda Puru Akar". *Buletin Tanaman Tembakau, Serat & Minyak Industri*, 9(2): 53-62. 2017.

[11] A.A. Hayati. "Potensi Konsorsium Rizobakteri dari Tumbuhan Solanaceae di UB Forest sebagai Bioprotektan dan Biostimulan pada

Tanaman Tomat". Skripsi. Jurusan Hama dan Penyakit Tumbuhan. Fakultas Pertanian. Universitas Brawijaya. Malang. 2018.

[12] L. Mudi, G.A.K. Sutariati, N. Hidayat, Faradilla, Rusmini, B. Winarni. "Biopriming benih dalam meningkatkan pertumbuhan dan hasil tanaman kacang tanah (Arachis hypogeae L.)". Agrovigor: Jurnal Agroekoteknologi. 15(2):140-146. 2022. https://doi.org/10.21107/agrovigor.v15i2.14664.

[13] Hamriani, Salimin, Ilmia. "Efektivitas Endo-Rhizo Bakteri Sebagai Pemacu Pertumbuhan dan Penginduksi Ketahanan Penyakit Blas Pada Padi Gogo Lokal". Laporan Akhir PKM-Penelitian. Kemenristek Dikti 2018.

[14] S.H., Hayat, M. Ahmad, K. Ali, M.A. Hayat, Z. Khan, Z. Cheng. "Aqueous Garlic Extract as a Plant Biostimulant Enhances Physiology, Improves Crop Quality and Metabolite Abundance, and Primes the Defense Responses of Receiver Plants". *Appl. Sci. 8*, 1505-1530. 2018.

[15] M. Kaushal, P. Mandyal, R. Kaushal. "Field Based Assessment of *Capsicum annuum* Performance with Inoculation of Rhizobacterial Consortia". *Microorganisms*, *7*(3), 89; 2019. https://doi.org/10.3390/microorganisms7030089.

[16] L. Mudi, Rusmini, G.A.K. Sutariati, T.C. Rakian, M. Yusuf. "Aplikasi rizobakteri asal rizosfer kelapa sawit terhadap vigor benih padi". Jurnal Agrotek Tropika, 11(3): 437 – 444. 2023. DOI : HTTP://DX.DOI.ORG/10.23960/JAT.V11I3.6657.

[17] S. H. Moran-Bañuelos, V. H. Aguilar-Rincón, T. Corona-Torres, E. Zavaleta-Mejía. "Resistencia de *Phytophthora capsici* Leon de chiles nativos del sur de Puebla, México". Revista de Fitotecnia Mexicana, 33: 21-26, 2010.

[18] Ropalia, R Apriyadi, H.M. Syaputra. "Penyakit Utama Tanaman Lada di Kabupaten Bangka Selatan". *Agrosaintek*, 6(1): 56-60. 2022.

[19] G. Santoyo, C.A. Urtis-Flores, P.D. Loeza-Lara, M.D.C. Orozco-Mosqueda, B.R. Glick. "Rhizosphere Colonization Determinants by Plant Growth-Promoting Rhizobacteria (PGPR)". *Biology (Basel)*. 2021 May 27; 10(6):475. doi: 10.3390/biology10060475. PMID: 34072072; PMCID: PMC8229920.

[20] Simon, Caulier, N. Catherine, G. Annika, L. Florent, B. Claude, M. Jacques. "Overview of the Antimicrobial Compounds Produced by Members of the *Bacillus subtilis* Group". *Frontiers in Microbiology*, 10(2019). DOI=10.3389/fmicb.2019.00302.

[21] H. Rahma, Nurbailis, N. Kristina. "Plant Growth Promoting Rhizobacteria (PGPR): as a Potential Biocontrol for *Curvularia lunata* Invitro". *Journal of Physics: Conference Series* 1940 (2021) 012091 doi:10.1088/1742-6596/1940/1/012091.

[22] S. Urainab, "Future Role of Bio-Microorganism Pesticide in Pakistan," *International Journal on Food, Agriculture and Natural Resources*, vol. 3, no. 1, Apr. 2022, doi: 10.46676/ij-fanres.v3i1.87.

[23] S. Hapsah, Yusnizar, Nura, K.S Kaloko, F. Reza, Firdaus. "Bio-priming of Aceh local chili seeds in the effort to increase production and begomo virus resistance". *IOP Conf. Series: Earth and Environmental Science*, 951 (2022) 012081. doi:10.1088/1755-1315/951/1/012081.

[24] J. M. Chin, Y.Y Lim, A.S.Y. Ting. "Biopriming *Pseudomonas fluorescens* to vegetable seeds with biopolymers to promote coating efficacy, seed germination and disease suppression". *Journal of the Saudi Society of Agricultural Sciences*. 2022. https://doi.org/10.1016/j.jssas.2022.02.002.

[25] I.C. Silaban, L.Q. Aini, M.A. Syib'li. "Pengujian konsorsium mikroba antagonis untuk mengendalikan jamur Sclerotium rolfsii penyebab penyakit rebah semai pada kedelai (*Glycine max* L.)". *J. Hama dan Penyakit Tumbuh*. 3 100 . 2015.

[26] B. Bukhari, N. Safridar. "Efisiensi penggunaan *Trichoderma* sp. untuk mengendalikan penyakit layu fusarium (*Fusarium oxysporium*) dan pertumbuhan bibit tanaman pisang". *J. Ilm. Pertan.* 14 14-28. 2018.

[27] D.A. Murtadho, L. Setyobudi, N. Aini. "Pengaruh plant growth promoting rhizobacteria (*Bacillus subtilis* dan *Pseudomonas fluorescens*) terhadap pertumbuhan dan hasil tanaman kentang (*Solanum tuberosum* L.) pada ketinggian 800 meter di atas permukaan laut". *Buana Sains* 16 143-150. 2017.

[28] B.G. Kelbessa, F. Ghadamgahi, P.L. Kumar, R. Ortiz, S.C. Whisson, R. Bhattacharjee, R.R. Vetukuri. "Antagonistic and plant growth promotion of rhizobacteria against *Phytophthora colocasiae* in taro". *Front Plant Sci.* 2022 Dec 2;13:1035549. doi: 10.3389/fpls.2022.1035549. PMID: 36531382; PMCID: PMC9755733.

[29] A. Munarti, Wulan, A. Utami. "Exploration and identification of arbuscular mycorrhizal fungi from the rhizosphere of chili plants (*Capsicum annuum* L.) in Bogor". *Journal of Science Innovare*. 1(2): 50-53. 2018.

[30] Mudi, L. & Rusmini. "Eksplorasi Rhizobakteri Indigenos dari Rizosfer Tanaman Kelapa Sawit (*Elais guinensis* Jack.) dan Uji Potensinya dalam Meningkatkan Vigor Benih". Laporan Hasil Penelitian Dosen Pemula. 2022. (Tidak Dipublikasi).

[31] N. Begum, L. Wang, H. Ahmad, K. Akhtar, R. Roy, M.I. Khan, T. Zhao. "Co-inoculation of Arbuscular mycorrhizal fungi and the plant growth promoting rhizobacteria improve growth and photosynthesis in tobacco under drought stress by upregulating antioxidant and mineral nutrition metabolism". *Microbial Ecology*, 83, 971-988. 2022. https://doi.org/10.1007/s00248-021-01815-7.

[32] Khoiri, S., Badami, K., Pawana, G., & Utami, C. S. (2021). Efektivitas Isolat-Isolat Bacillus sebagai Pengendali Penyakit Bulai dan Pemacu Pertumbuhan Tanaman Jagung pada Kondisi Terkontrol. Rekayasa, 14(2), 144-151. 2021.

[33] A. Munawar, "Kesuburan Tanah dan Nutrisi Tanaman". Institut Pertanian Bogor Press. Bogor. 2011.

[34] H. Malhotra, S. Sharma, R. Pandey, "Phosphorus nutrition: plant growth in response to deficiency and excess. In: Plant nutrients and abiotic stress tolerance". Singapore: Springer, pp. 171– 190. 2018.

[35] M. Satyaprakash, T. Nikitha, E.U.B. Reddi, B. Sadhana, S.S. Vani. "Phosphorous and phosphate solubilizing bacteria and their role in plant nutrition". *International Journal of Current Microbiology and Applied Sciences*, 6(4), 2133– 2144. 2017.

[36] J.L. Havlin, J.D. Beaton, S.L. Tisdale and W.L. Nelson. "Soil Fertility and Fertilizers. An introduction to nutrient management". Seventh Edition. Pearson Education Inc. Upper Saddle River, New Jersey. 2005.

[37] A.V. Barker, D.J. Pilbeam. "Hand Book of Plant Nutrition". CRC Press. New York. 2007.

[38] F.U. Rehman, M. Kalsoom, M. Adnan, M. Toor, A. Zulfiqar. "Plant growth promoting rhizobacteria and their mechanisms involved in agricultural crop production: a review". *SunText Review of BioTechnology*, 1(2), 1– 6. 2020.

[39] B.A. Bhat, L. Tariq, S. Nissar, S.T. Islam, S.U. Islam, Z. Mangral. "The role of plant-associated rhizobacteria in plant growth, biocontrol and abiotic stress management". *Journal of Applied Microbiology*, 133, 2717–2741. 2022. Available from: https://doi.org/10.1111/jam.15796.

[40] B. Lahati, Z. Abdullatif, F. Kaddas, and M. Labaradji, "The Potential of Trichoderma sp. as Biological Agent to Support the Germination of Corn Seeds (Zea Mays)," *International Journal on Food, Agriculture and Natural Resources*, vol. 2, no. 2, pp. 27–30, Aug. 2021, doi: 10.46676/ij-fanres.v2i2.33.

[41] G.A.K. Sutariati, T.C. Rakian, A. Madiki, N.M. Rahni, G.N.A. Wibawa, L. Mudi. "Effectiveness of a single and a mixture treatments of rhizobacteria in increasing the growth and yield of hot pepper (*Capsicum annuum* L.)". IOP Conference Series: Earth and Environmental Science, 977(1): 012044. 2022. doi=10.1088/1755-1315/977/1/012044.

[42] Z. Resti, E. Sulyanti, R. Reflin. "Endophytic bacterial consortium as biological control to *Ralstonia solanacearum* and growth promoter for chili plant". *Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia* pp. 208-214. 2018.