LenteraBio
Berkala Ilmiah Biologi

LenteraBio, 2026; Volume 15, Issue 2: 207-214

p-ISSN: 2252-3979 e-ISSN: 2685-7871
https://journal.unesa.ac.id/index.php/lenterabio/index

Antagonistic Test of Potential Bacteria for Glyphosate Degradation as a Basis for Determining the Formulation of Biodegradation Agents

Salshabilla Berliana Siswanta*, Lisa Lisdiana
Study Program of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya Kampus Unesa 1, Jln. Ketintang Surabaya 60231 Indonesi
*salshabillaberliana.21046@mhs.unesa.ac.id

Article History:
Received:
9-January-2026
Revised:
5-May-2026
Available online:
31-May-2026
Published regularly:
31-May-2026

Abstract
Previous study found an isolate, termed Cf11, recommended as glyphosate herbicide-degrading agent. However, isolate Cf11 can only be found growing at a glyphosate concentration of 50 ppm and not at a lower concentration of 25 ppm, indicating possible antagonistic interactions between other bacteria on 25 ppm and Cf11. Therefore, it is necessary to conduct an antagonistic test between isolate Cf11 with isolates Cf1 and Cf7, which are only found growing on 25 ppm glyphosate media. This research aims to determine the compatibility of Cf11 isolates with other bacterial isolates to recommend formulation of biodegradation agents. The antagonist test method used in this study is Kirby-Bauer. The test results showed no antagonistic interaction between bacterial isolates Cf1 and Cf11 and between bacterial isolates Cf1 and Cf7. As for the bacterial isolate Cf7 with Cf11, there was a weak antagonistic interaction with an antagonistic efficiency index value of 0.85 mm at 24 hours incubation and 0.71 mm at 48 hours incubation. The existence of antagonistic interactions between Cf11 and Cf7 isolates may be the causes of the absence of Cf11 isolates at a concentration of 25 ppm glyphosate, so that the two cannot be consorted together as biodegradation agents. However, due to the weak antagonism interaction, it is likely that there are other factors that strengthen the antagonism interaction.

Keywords: bacteria interaction; antagonistic efficiency index; biodegradation; waste management
How to Cite: Siswanta SB, Lisdiana L, 2026. Antagonistic test of potential bacteria for glyphosate degradation as a basis for determining the formulation of biodegradation agents. LenteraBio; 15(2): 207-214.
DOI: https://doi.org/10.26740/lenterabio.v15n2.p2017-214

INTRODUCTION

Glyphosate is part of the organophosphates that have non-selective systemic biocide properties with broad-spectrum activity. Many commercial herbicide formulations use glyphosate as the main ingredient in tackling crop weeds. Excessive and long-term use of glyphosate herbicides in agriculture can lead to the accumulation of glyphosate in soil and water (Marble et al., 2020). Glyphosate herbicide residues in water and agricultural commodities can have negative impacts on humans and animals (Ferreira et al., 2022). Accumulation of glyphosate in the environment also can occur due to the non-degradable nature of glyphosate and its ability to form strong bonds with soil (Mertens et al., 2018). The accumulation of glyphosate herbicide in the environment can be minimized by accelerating the glyphosate degradation process. Glyphosate degradation can be done throught bioremediation (Singh et al., 2020)

Research on microbial agents from cayenne pepper agricultural soil that have the potential to degrade glyphosate herbicides has been conducted by Nikmah and Lisdiana (2024) and Maulida and Lisdiana (2024). Nikmah and Lisdiana (2024) conducted a screening and characterization of rhizosphere bacterial isolates that have the potential to degrade glyphosate herbicide from cayenne pepper agricultural soil samples in Sumberagung Village, Blitar. The screening of rhizosphere bacterial isolates was carried out using three different concentration levels of glyphosate, namely 25 ppm, 50 ppm, and 100 ppm. Based on the results of rhizosphere bacteria screening by Nikmah and Lisdiana (2024), 14 bacterial isolates were obtained with the code name Cf (*Capsicum frutescent* L.). The isolates code of rhizosphere bacteria are as follows, Cf1, Cf2, Cf3, Cf4, Cf5, Cf6, Cf7, Cf8, Cf9, Cf10, Cf11, Cf12, Cf13, and Cf14.

Different composition of bacterial isolates found at growth media with varies glyphosate concentrations. Bacterial isolates only found at 25 ppm and 50 ppm of glyphosate concentration. At a

OPEN ACCESS

concentration 25 ppm glyphosate, ten bacterial isolates were found, namely Cf1, Cf2, Cf3, Cf4, Cf5, Cf6, Cf7, Cf8, Cf9, and Cf10. While, at a concentration of 50 ppm seven isolates were found, namely Cf2, Cf3, Cf6, Cf11, Cf12, Cf13, and Cf14. Based on the average number of growing colonies, there are three isolates that have the highest average number of colonies, namely isolates Cf6, Cf2, and Cf11 (Nikmah and Lisdiana, 2024). Isolate Cf6 is a bacterial isolate with the highest average number of colonies, namely 14 at 25 ppm glyphosate concentration and 19 at 50 ppm concentration. Isolate Cf2 has an average number of colonies of 11 at concentrations of glyphosate 25 ppm and 50 ppm. Isolate Cf11 has an average number of 11 colonies that only grow at a concentration of 50 ppm and not found at a concentration of 25 ppm.

Based on the results of bacterial screening conducted by Nikmah and Lisdiana (2024) to the three bacterial isolates with the highest number of colonies, isolate Cf11 is the only isolate that can only be found growing at a glyphosate concentration of 50 ppm and not found at a lower concentration of 25 ppm. Generally, if a bacterium can grow with a large number of colonies in an environment with high chemical concentration, then the bacteria can also be found in an environment with lower chemical concentration. This is in accordance with research from Pratiwi et al., (2012) regarding the isolation and characterization of dicofol pesticide degrading bacteria from rice field soil in Karawang Regency. Isolates of degrading bacteria were tested for resistance using dicofol variations of 20, 30, 40, 50, 60, 70, 80, and 90 ppm. The results of the study showed that bacterial isolates found at high dicofol concentrations could also be found at low dicofol concentrations. Based on this research, isolate Cf11 which was found in a large number of colonies at a glyphosate concentration of 50 ppm should also be found at a concentration of 25 ppm.

The growth of bacterial isolates can be influenced by several factors, one of which is the presence of antagonistic interactions between bacterial isolates. The possibility of antagonistic interactions between Cf11 and other bacterial isolates that growth at 25 ppm glyphosate concentration can be the cause of the absence of Cf11 isolates at 25 ppm concentration. Antagonistic interaction is the activity of inhibiting the growth and development of an organism by another organism. The possibility of antagonistic interactions is also reinforced by a statement from Peterson et al. (2020) in their research on the main role of interbacterial antagonism in bacterial growth and development which states that all bacterial phyla are proven to have antagonistic pathways either through direct or indirect contact. Antagonistic mechanisms between bacteria vary in terms of phylogenetic spectrum and genetic code.

The compatibility of bacterial isolates is one of the important factors that support the effectivity of glyphosate degradation process. For this reason, it is necessary to test the antagonism of Cf11 isolates with bacterial isolates that grow at a concentration of 25 ppm glyphosate and do not grow at a concentration of 50 ppm.

Bacterial isolates Cf1 and Cf7 are two isolates that are only found to grow at a concentration of 25 ppm and have an average number of colonies that are quite a lot compared to other isolates that grow at a concentration of 25 ppm. Isolate Cf1 has an average number of colonies of four, while isolate Cf7 has an average number of colonies of six. The large average number is one of the factors that may have a major effect on their interaction with Cf11. Antagonistic tests of rhizosphere bacteria between isolates Cf1, Cf7, and Cf11 are important to do as a basis for determining the right glyphosate biodegradation formulation. Formulation is an important aspect in the future application of a product because it plays a role in knowing the effectiveness of a product's work.

A proper biodegradation agent formulation is a composition consisting of agents that work synergistically with each other. Antagonistic bacteria can inhibit and reduce the effectiveness of the formulation. Cf11 bacterial isolate is one of the bacterial isolates that has high potential as a degrading agent, so it will be included in the glyphosate degrading agent formulation. Therefore, it is necessary to conduct an antagonist test to determine the bacterial isolates that are antagonistic to the Cf11 isolate. From the antagonistic test between bacterial isolates Cf1 and Cf7 with potential bacterial isolate Cf11, it is expected that the compatibility between the three isolates can be known, as a reference in the formulation of glyphosate herbicide degrading agent in the future.

MATERIALS AND METHODS

This research uses descriptive research with observation techniques because it aims to determine the antagonistic interaction between rhizosphere bacterial isolate Cf11 with bacterial isolate Cf1, isolate Cf11 with isolate Cf7, and isolate Cf1 with Cf7 from the screening results of Nikmah and Lisdiana (2024) by observing the size of the inhibition zone formed. The research was conducted at the

Microbiology Laboratory, Faculty of Mathematics and Natural Sciences, State University of Surabaya. This research conducted from March to May 2025.

This research began with preparing growth media. After growth media preparation, bacterial isolates were recultured using the streak method as much as one ose on to Nutrient Agar (NA) media and NA + glyphosate media. The bacterial isolates were then incubated for ± 24 - 48 hours at room temperature until bacterial colony isolates grew.

Gram staining was done by standard method (Smith and Hussey, 2005) and observed under a microscope with 1000× magnification. Gram-positive bacteria cells were purple colored, while gram-negative bacteria cells were pink or red colored.

Determination of Gram type bacteria not only using Gram staining but also by using 3% KOH test. The KOH test was done by standard method (Smith and Hussey, 2005). Gram-negative bacteria are characterized by the presence of mucus, while gram-positive bacteria are characterized by the absence of mucus.

Preparation of bacterial suspensions with number of bacteria approximately 1.5×10^8 CFU/mL was carried out by comparing the turbidity of the bacterial suspension with the 0.5 standard Mc-Farland solution made based on the protocol from Hudzicki (2009). The 0.5 standard Mc-Farland solution was prepared by mixing 99.5 mL of 1% sulfuric acid (H_2SO_4) and 0.5 mL of 1.175% barium chloride ($BaCl_2$).

Bacterial suspension solution was made by taking four or five ose of bacteria and put into a test tube containing 2 ml of 0.9% physiological saline solution (NaCl). The suspension was then vortexed until homogeneous, then compared with Mc-Farland 0.5 standard solution with a distance of 2.54 cm or 1 inch in front of the Wickerham card (card with black and white blade print) with adequate light (Hudzicki, 2009). The two solutions were then equalized turbidity, if the level of turbidity was different, then the number of bacteria can be added if less turbid and added sterile NaCl solution if too turbid. The bacterial isolate suspension can be used no more than 15 minutes after preparation.

Antagonistic tests were carried out using the pour plate method and continued with disk diffusion or Kirby-Bauer. Tests were carried out with 3 replicates according to the research method of Salsabilla and Trimulyono (2022). The total number of tests was 12 tests consisting of nine treatments and three negative controls. The negative control used disk that has been soaked into aquades. The diffusion disc used in this study is a standardized diffusion disc. The disk is soaked in bacterial suspension for ± 1 minute and dried for 2-3 minutes. The disk is then inoculated in the center of the petri dish which is 4 cm from the edge of the petri dish, the total disks used in one petri dish media are two. Petri dishes that have been inoculated with bacterial isolates are then incubated at 25-30˚C for 24 and 48 hours. After the incubation period of 24 and 48 hours, observations were made on the formation of inhibition zones around the disk. Formed inhibition zone was measured using a ruler.

Data were obtained from direct observation on the growth media of bacterial isolate Cf1 with Cf11, bacterial isolate Cf7 with C11, and bacterial isolate Cf1 with Cf7. Observations include the diameter of the inhibition zone formed and the observation time, namely 24 hours and 48 hours after incubation. The results of the inhibition zone calculation were then used to calculate the antagonistic efficiency index (Ant-EI) using the formula of El-Sayed et al. (2014).

Ant-EI (Antagonist Efficiency Index) = (inhibition zone diameter (mm))/(bacterial colony growth diameter (mm)).

The antagonist efficiency index formed was categories into three group based on Duman and Soylu (2019) described on **Table 1**.

Table 1. Bacterial antagonist efficiency index categorization according to Duman and Soylu (2019)

Antagonist Efficiency Index	Categories
> 3	Strong
2-3	Average
< 2	Weak

RESULTS

The results of Gram staining and 3% KOH test showed that the types of rhizosphere bacterial isolates Cf1, Cf7, and Cf11 were Gram-positive bacteria. This is indicated by the color response of bacterial isolate cells stained purple on observation with a 1000 times magnification microscope shown in Figure 12. The results of Gram staining were also supported by the results of the 3% KOH test which shows no mucus formed on the three isolates.

The results of the antagonistic test between rhizosphere bacterial isolates Cf1 and Cf11, repeated three times, showed no antagonistic interaction between the two isolates. The absence of antagonistic interaction can be seen in **Figure 2.** There was no inhibition zone was formed to separate the Cf1 bacterial isolate on the diffusion disk from the Cf11 isolate grown on the medium. The colonies of the Cf1 bacterial isolate and Cf11 isolate coexist with each other. The number of colonies appeared to be greater on the medium incubated for 48 hours compared to that incubated for 24 hours (Figure 2).

Unlike the antagonistic test between Cf1 and Cf11, which showed no antagonistic interaction, the antagonistic test between bacterial isolate Cf7 and Cf11 revealed an antagonistic interaction between the two, as shown in **Figure 3**.

Based on the results of the antagonistic test of isolate Cf7 with Cf11 in **figure 3**, it shown that there was an inhibition zone formed, separating the bacterial colonies of isolate Cf7 and Cf11. The inhibition zone formed was a hazy zone, with a few bacterial colonies still growing within the inhibition zone. The number of colonies growing appears to be greater on the medium incubated for 48 hours compared to the medium incubated for 24 hours. Unlike the results of the antagonistic test between isolates Cf7 and Cf11, the results of the antagonistic test between bacterial isolates Cf1 and Cf7 show non-antagonistic results (**Figure 4)**.

Based on the results of the antagonistic test of bacterial isolates Cf1 and Cf7 in **figure 4**, it shown that the two isolates were not antagonistic to each other. This is based on the absence of an inhibition zone separating the Cf1 bacterial colony on the medium from the Cf7 bacterial colony growing around the diffusion disk. The two bacterial isolate colonies coexist with each other. As for the number of bacterial colonies between 24-hour and 48-hour growth, no significant differences were observed.

For the negative control between the bacterial isolates and distilled water, no antagonistic interactions were detected shown in **Figure 5**.

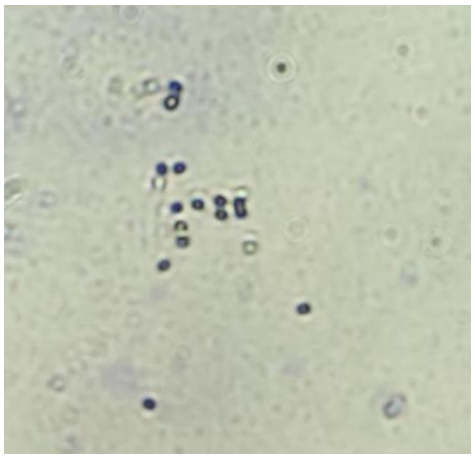


Figure 1. Gram stain results of isolate Cf1 magnification 1000×



Figure 2. Results of the antagonistic test of (1) Isolate Cf1 with Cf11 incubated for 24 hours (isolate Cf1 on disk diffusion and Cf11 on media); (2) Isolate Cf1 with Cf11 incubated for 48 hours

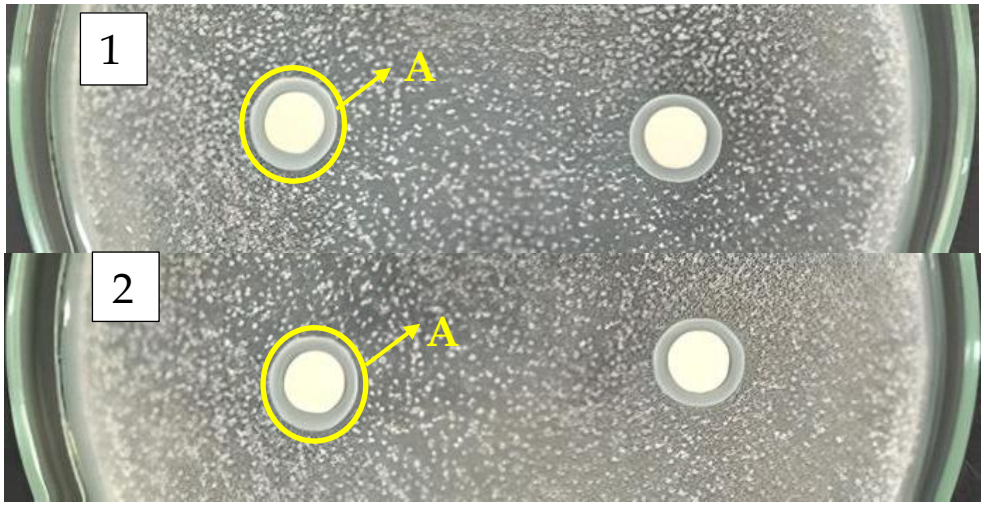


Figure 3. Results of the antagonistic test of (1) Isolate Cf7 with Cf11 incubated for 24 hours (isolate Cf7 on disk diffusion and Cf11 on media); (2) Isolate Cf7 with Cf11 incubated for 48 hours; (A) Inhibition zone

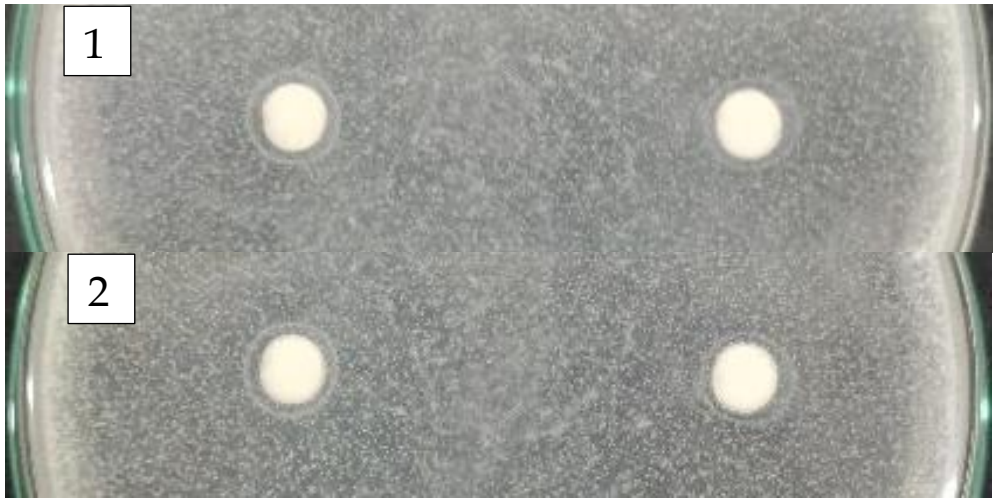


Figure 4. Results of the antagonistic test of (1) Isolate Cf1 with Cf7 incubated for 24 hours (isolate Cf7 on disk diffusion and Cf1 on media); (2) Isolate Cf1 with Cf7 incubated for 48 hours

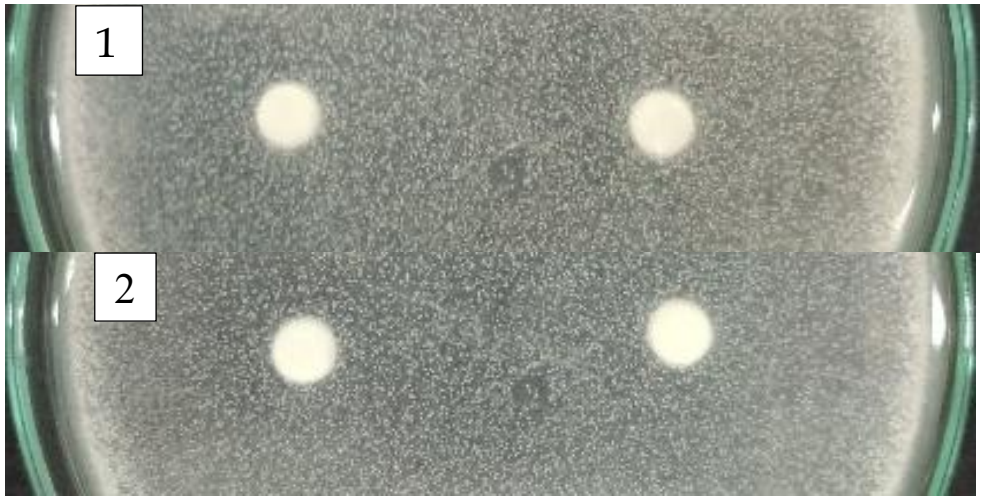


Figure 5. Results of the antagonistic test of (1) Distilled water with Cf1 isolate incubated for 24 hours (distilled water on a diffusion disk and Cf1 on media); (2) Distilled water with Cf1 incubated for 48 hours

Based on the results of the antagonist test on negative controls between distilled water and bacterial isolates, it was found that no inhibition zone was formed. In contrast to the bacterial isolates grown on the disk, no colonies grew from the disk in the negative control test because the disk was only immersed in sterile distilled water. Based on **Figure 5**, it was also found that there was no significant difference in the number of colonies visible on the medium.

The results of the antagonistic test between bacterial isolates Cf1 and Cf11, isolates Cf7 and Cf11, and isolates Cf1 and Cf7 were then calculated using the antagonistic efficiency index formula developed by El-Sayed et al. (2014) (Table 2).

Table 2. Antagonist efficiency index between Cf1, Cf7, and Cf11 isolate

Bacteria Isolate	Antagonist Efficiency Index	
	24 Hour Incubations	48 Hour Incubations
Cf1 with Cf11	0.00	0.00
Cf7 with Cf11	0.85	0.71
Cf1 with Cf7	0.00	0.00

Based on the results of the antagonistic efficiency index calculation using the formula of El-Sayed et al. (2014), it was found that isolates Cf1 with Cf11 and Cf7 with Cf11 had an antagonistic efficiency index of 0.00 at 24 and 48 hours of incubation because no inhibition zone was formed. However, in the antagonistic interaction between isolate Cf7 and Cf11, an inhibition zone was formed, allowing the calculation of the antagonistic efficiency index. The value of the antagonistic efficiency index for the Cf7 isolate with Cf11 was classified as weak, because the average value was below the standard, which was 0.85 at 24 hours of incubation and 0.71 at 48 hours of incubation.

DISCUSSION

Based on the results of the antagonistic test of bacterial isolate Cf1 with Cf11, isolate Cf7 with Cf11, and isolate Cf1 with isolate Cf7, it was known that isolate Cf1 with Cf11 and isolates Cf1 and Cf7 were not antagonistic. Because there was no inhibition zone in the form of a clear zone or fog zone in the antagonist test, the antagonist efficiency index value was 0.00. This results in accordance with research from Hartanti (2020), in which four bacterial isolates EPS1, EPSI2, EPSI3, and EPSI4 are not antagonistic because they do not show the presence of a bacterial inhibition zone and bacteria can grows in contact with each other.

The isolate Cf7 with Cf11 was known to have antagonistic interactions, which indicated by the inhibition zone that separates the colonies of isolate Cf7 with Cf11. This finding in accordance with the research of Prihatiningsih et al. (2015) that antagonistic interactions can be known from the formation of inhibition zones on culture media. The antagonistic interaction of isolate Cf7 with Cf11 produces an inhibition zone in the form of a fog zone. The fog zone is an inhibition zone where bacteria can still be found growing in small numbers, so it is different from the clear zone which shows that no bacteria grow. The fog zone indicates that the antagonistic activity that occurs is relatively weak, while the clear zone indicates that the antagonistic activity is strong (Purniasih et al., 2022).

The existence of a fog zone in antagonistic research has been found in the research of Purniasih et al. (2022) regarding antagonistic tests between isolates of seagrass symbiont bacteria Enhalus acoroides against *Escherichia coli, Salmonella typhi, Staphylococcus aureus,* and *Staphylococcus mutans*. Antagonistic interactions that occur between bacterial isolates and pathogenic bacteria are categorized into weak antagonistic interactions, because the diameter of the inhibition zone is small and the inhibition zone is found in the form of a fog zone which indicates that there are still bacteria growing in the inhibition zone.

In addition to the zone of inhibition in the form of a fog zone, the antagonistic efficiency index of isolate Cf7 with Cf11 also shows that the antagonistic interaction between the two is a weak antagonistic interaction, with the value below the standard (<2). The antagonistic efficiency index of bacterial isolates Cf7 with Cf11 was 0.85 at 24 hours incubation and 0.71 at 48 hours incubation. The antagonistic efficiency index indicates the degree of influence of colony growth on the formation of the inhibition zone. A high antagonistic efficiency index indicates a small number of bacterial colonies but produces a large inhibition zone (Duman and Soylu, 2019).

There are several possible antagonistic mechanisms that may occur in bacterial isolates Cf7 with Cf11. Antagonism mechanisms between bacteria can occur with several mechanisms both contact

dependent and contact-independent. Contact dependent is a bacterial antagonistic interaction that uses a lot of help from specialized secretion systems including the Esx secretion system in gram-positive bacteria (Peterson et al., 2020). The Esx secretion system is a specialized secretion system to transport proteins across complex cell walls. This system is found in most Gram-positive bacteria and is generally referred to as type VII secretion. This system functions in mediating various functions ranging from conjugation to metabolic regulation (Poweleit et al., 2019).

Although the mechanism that occurs between isolate Cf7 and Cf11 has not been confirmed, there is a possibility that the antagonism mechanism that occurs in isolate Cf7 with Cf11 is a combination of various antagonistic mechanisms. Research from Lee et al. (2023) regarding several mechanisms, interactions, and applications of several genus of bacteria as biocontrol agents also mentioned that a bacterium can have various antagonism pathways. In this study, biocontrol agents such as bacteria from the genus *Bacillus, Streptomycetes, Pseudomonas,* and *Serratia* are known to have antagonistic interactions with various plant pathogens through different antagonistic mechanisms. Bacteria of the *Bacillus* genus can inhibit the growth of plant pathogens such as *Ralstonia, Penicillium,* and *Erwina*. *Bacillus amyloliquefaciens* (BA) secretes unstable organic components to inhibit Penicillium digitatum *Ralstonia solanacearum*. *Bacillus subtilis* BS-1 produces AiiA which can reduce symptoms in plants infested with *Erwinia carotova*.

This is in accordance with research from Peterson et al. (2020) which states that an individual bacterium can code for various antagonistic pathways, such as in *Pseudomonas aeruginosa* which codes for at least six antagonistic pathways. The diversity of antagonism pathways is influenced by the number of antagonistic mechanisms possessed by the species, the various transfer pathways of toxic secretion, and the excess of effectors sent from a single transport system.

The antagonistic interaction between bacterial isolate Cf11 and isolate Cf7 is the cause of the absence of isolate Cf11 on media with glyphosate concentration of 25 ppm in the screening of glyphosate-degrading bacterial isolates by Nikmah and Lisdiana (2024). Bacterial isolate Cf7 was only found to grow on media with glyphosate concentration of 25 ppm and was not found to grow on media with glyphosate concentration of 50 ppm where isolate Cf11 was found. Although it is known that there is an antagonistic interaction between isolate Cf7 and Cf11, further tests on the mechanism of antagonism in isolate Cf7 with Cf11 is needed. Further testing is also needed regarding the effect of other isolates that grow on 25 ppm concentration media and also the consortium of isolate Cf7 with other bacterial isolates that grow on 25 ppm concentration media on bacterial isolate Cf11. This is because the antagonistic interaction that occurs between bacterial isolate Cf7 and Cf11 is a weak antagonistic interaction with low inhibitory power. Therefore, there is a possibility that the absence of Cf11 isolates on media with a concentration of 25 ppm is due to the influence of cooperation between bacterial isolate Cf7 with other bacterial isolates that grow on media concentration of 25 ppm. Cooperation between bacterial isolates that grow on 25 ppm concentration media is likely the one that strengthen the antagonistic interactions against Cf11 isolates.

The possibility of antagonistic interactions of other bacterial isolates against Cf11 is important to know because of the potential of Cf11 bacterial isolates as potential glyphosate degrading bacteria. The existence of antagonistic interactions between bacteria is one of the requirements for the use of a bacterial isolate as a biodegradation agent. This is because a biodegradation agent is generally a consortium and not a single isolate. Bacterial consortium is a mixture of bacterial populations in the form of communities that have cooperative, commensalism, and mutualistic relationships (Kawuri et al., 2023). Based on research from Kawuri et al. (2023) on the formulation and application of molasses-based bacterial consortium to degrade waste oil and fat in the environment. The results showed that a synergistic bacterial consortium can work effectively in the treatment of fat waste in an environment polluted with fat and oil waste. Therefore, a biodegradation agent that cooperates with each other is needed.

CONCLUSION

Based on the results of antagonistic tests conducted on rhizosphere bacterial isolates Cf1, Cf7, and Cf11, it can be concluded that there is no antagonistic interaction between rhizosphere bacterial isolates Cf1 and Cf11, and isolates Cf1 and Cf7 which is characterized by the absence of inhibition zone separating the two colonies. However, there is an antagonistic interaction between rhizosphere bacterial isolates Cf7 and Cf11 which is characterized by the presence of an inhibition zone separating the two isolates. The inhibition zone formed in the form of a fog zone with an average antagonistic efficiency index of 0.85 mm at 24 hours incubation and 0.71 mm at 48 hours incubation.

ACKNOWLEDGEMENTS

We would like to thank article reviewers for their help in improving this study. We also thank Mrs. Alvi Lailatun Nikmah for the bacteria isolate that has been used in this research.

CONFLICT OF INTEREST

There is no conflict of interest.

REFERENCES

Duman K, Soylu S, 2019. Characterization of plant growth-promoting traits and antagonistic potentials of endophytic bacteria from bean plants against *Pseudomonas syringae* pv. *phaseolicola*. *Plant Protection Bulletin*; 59(3): 59–69. DOI:10.16955/bitkorb.597214

El-Sayed WS, Akhkha A, El-Naggar MY, and Elbadry M, 2014. In vitro antagonistic activity, plant growth promoting traits and phylogenetic affiliation of rhizobacteria associated with wild plants grown in arid soil. *Frontiers in Microbiology*; 5: 651. DOI:10.3389/fmicb.2014.00651

Ferreira CC, Durán R dan Faro LRF, 2022. Toxic Effects of Glyphosate on the Nervous System: A Systematic Review. *International Journal of Molecular Sciences*; 23(9): 4605. DOI: 10.3390/ijms23094605

Hartanti DAS, 2020. Isolasi dan Uji Sinergisme Bakteri Endofit Tanaman Padi (*Oryza sativa L*) untuk Konsorsium Biofertilizer. *Agroradix*; 3(2): 23-30.

Hudzicki J, 2009. Kirby-Bauer Disk Diffusion Susceptibility Test Protocol. American Society for Microbiology. https://asm.org/protocols/kirby-bauer-disk-diffusion-susceptibility-test-pro.

Kawuri R, Darmayasa IBG, Widyastama IKA dan Putri RJ, 2023. Formulation and Application of Molasses-Based Bacterial Consortium to Degrade Waste Oil and Fat in the Environment. *Metamorfosa: Journal of Biological Sciences*; 10(2): 285–291.

Lee J, Kim S, Jung H, Kyoung-Koo B, Han JA, and Seok Lee H, 2023. Exploiting Bacterial Genera as Biocontrol Agent: Mechanisms, Interactions, and Applications in Sustainable Agriculture. *Springer Nature*; *Journal of Plant Biology*; 66: 485-498.

Marble C, Neal J, and Senesac A, 2020. Use of Glyphosate and Herbicide Alternatives for Weed Control In Florida Landscape Planting Beds. *UF; IFAS Extension University of Florida*; 2020(1): 1-10. DOI: 10.32473/edis-ep580-2020

Maulida KZR, and Lisdiana L, 2024. Identifikasi Secara Fenotipik dan Genomik Isolat Bakteri Potensial Pendegradasi Herbisida Glifosat dari Rhizosfer Cabai Rawit. *LenteraBio : Berkala Ilmiah Biologi*; 13(2): 253–261. DOI: 10.26740/lenterabio.v13n2.p253-261

Mertens M, Höss S, Neumann G, Afzal J dan Reichenbecher W, 2018. Glyphosate, a Chelating Agent—Relevant for Ecological Risk Assessment? Environmental Science and Pollution Research; 25(6): 5298–5317.

Nikmah AL, and Lisdiana L, 2024. Penapisan Bakteri Rizosfer Pendegradasi Herbisida Glifosat dari Tanah Pertanian Cabai Rawit (*Capsicum frutescent L.*). *LenteraBio : Berkala Ilmiah Biologi*; 13(1): 24–31. DOI: 10.26740/lenterabio.v13n1.p24-31

Peterson SB, Bertolli SK, and Mougous JD, 2020. Interbacterial Antagonism: at The Center of Bacterial Life. *HHS Public Access; Physiology and Behavior*; 176(1): 100–106. DOI: 10.1016/j.cub.2020.06.103.

Pratiwi AA, Suprihadi A, Raharjo B, Wahyudi P, and Parmiyatni S, 2012. Isolasi dan Karakterisasi Bakteri Pendegradasi Pestisida Dicofol dari Tanah Sawah di Kabupaten Karawang. *Jurnal Biologi*; 1(1): 23–32.

Prihatiningsih N, Arwiyanto T, Hadisutrisno B, and Widada J, 2015. Mekanisme Antibiosis *Bacillus Subtilis* B315 untuk Pengendalian Penyakit Layu Bakteri Kentang. *Jurnal Hama dan Penyakit Tumbuhan Tropika*; 15(1): 64-71. DOI: 10.23960/j.hptt.11564-71

Poweleit N, Czudnochowski N, Nakagawa R, Trinidad DD, Murphy KC, Sassetti CM, and Rosenberg, OS, 2019. The structure of the endogenous ESX-3 secretion system. *eLife*; 8: e52983. DOI: 10.7554/eLife.52983

Purniasih NKP, Ginting EL, Wullur S, Mangindaan REP, Rumampuk NDC, and Pratasik SB, 2022. Antibacterial Activity of Endophytic Bacteria of Seagrass Symbiont *Enhalus acoroides* from Tiwoho Waters, North Minahasa. *Jurnal Ilmiah Platax*; 10(2): 402-414. DOI: 10.35800/jip.v10i2.42485

Salsabilla KN, and Trimulyono G, 2022. Isolasi dan Uji Antagonis Bakteri Asam Laktat dari Tape Pisang Kepok terhadap *Escherichia coli* Isolation. *LenteraBio: Berkala Ilmiah Biologi*; 11(3): 430–440.

Singh S, Kumar V, Gill JPK, Datta S, Singh S, Dhaka V, Kapoor D, Wani AB, Dhanjal DS, Kumar M, Harikumar SL, and Singh J, 2020. Herbicide Glyphosate: Toxicity and Microbial Degradation. *International Journal of Environmental Research and Public Health*; 17(20): 1–18. DOI: 10.3390/ijerph17207519

Smith AC dan Hussey MA, 2005. Gram Stain Protocols. American Society for Microbiology. https://asm.org/protocols/gram-stain-protocols.