Short Communication:  
Antibacterial potential of Actinomycetes isolated from mangrove sediment in Tanjung Api-Api, South Sumatra, Indonesia

ROZIRWAN*, HEBBRI ISKANDAR MUDA, TENGKU ZIA ULQODRY
Department of Marine Science, Faculty of Mathematics and Natural Sciences, Universitas Sriwijaya. Jl. Palembang-Prabumulih Km. 32, Indralaya, Ogan Ilir 30128, South Sumatra, Indonesia. Tel./fax.: +62-711-663375, *email: rozirwan@unsri.ac.id

Manuscript received: 22 October 2020. Revision accepted: 23 November 2020.

Abstract. Rozirwan, Muda H1, Ulqodry TZ. 2020. Short Communication: Antibacterial potential of Actinomycetes isolated from mangrove sediment in Tanjung Api-Api, South Sumatra, Indonesia. Biodiversitas 21: 5723-5728. Actinomycetes play an important role in the decomposition process of organic matter in mangrove sediments. This study was carried out to identify and evaluate the antagonistic activity of actinomycetes from mangrove sediment against Escherichia coli and Staphylococcus aureus. Identification of actinomycetes was performed based on morphological dan physiological characters. The antagonistic test was carried out against Escherichia coli and Staphylococcus aureus. A total of ten isolates had been successfully isolated and grouped into eight genera, including; Oerskovia H1, Micrococcus H2, Nocardia H3, Sporichthya H5, Corynebacterium H6, Jonesia H7, Actinomyces H10, and Streptomyces H8, H11, H12. Actinomycetes from mangrove sediment were gram-positive bacillus. The shape of the colony varied from circular to filamentous and irregular, with medium and large colony sizes. The colony appears white or yellow. The surface is convex and flat, aerobes and facultative anaerobes; capable of fermenting glucose. Five isolates have very strong growth inhibition activity against E. coli: Nocardia H3 (27.81mm ± 1.39), Actinomyces H10 (27.75mm ± 2.48), Corynebacterium H6 (27.69mm ± 2.39), Micrococcus H2 (18.55mm ± 2.44), and Streptomyces H8 (17.92mm ± 2.70) while Streptomyces H8 (24.83mm ± 2.08), and Actinomyces H10 (16.06mm ± 2.49) were active against S. aureus.

Keywords: Actinomycetes, antagonist test, Escherichia coli, mangrove sediment, Staphylococcus aureus

INTRODUCTION

Actinomycetes bacteria are grouped into gram-positive bacteria capable of producing various bioactive compounds (Kumar et al. 2019; Mahapatra et al. 2019; Kavitha and Vimala 2020; Shamikh et al. 2020). Actinomycetes are potential as antioxidant, antibacterial, antifungal, antifouling, antiviral (Chandra et al. 2020; Elkhateeb et al. 2020; Gacen et al. 2020; Gong et al. 2020; Hamed et al. 2020; Hassan et al. 2018; Kumar et al. 2020; Matthew et al. 2020; Pereira et al. 2020; Shaali et al. 2020; Yi et al. 2020). Therefore, the potential of marine natural products from actinomycetes collected from mangrove sediments needs to be explored.

Actinomycetes bacteria are found in muddy substrates, especially in mangrove areas. This area contains high nutrients, which come from the mainland through rivers and rainwater runoff. Organic materials from the land will be deposited in the mangrove area to form a thick mud. Mangrove ecosystems contribute very large amounts of nutrients to mangrove sediments (Reef et al. 2010). Mangrove sediments have an abundance of bacteria for the decomposition process that results in increasing soil fertility. It is also reported that actinomycetes can degrade waste (Waithaka et al. 2019).

Actinomycetes are the most widely distributed in mangrove sediments (Suresh et al. 2020). Actinomycetes exhibit antagonistic properties (Tistechok et al. 2019; Dede et al. 2020; Talpur et al. 2020). They can survive in a dynamic mangrove environment, such as changes in salinity, oxygen, temperature, pH, etc. Mangrove areas are greatly influenced by tides, salinity, pH, currents, temperature, and dissolved oxygen (Imamsyah et al. 2020).

The antagonist test was chosen because it is the most effective method for screening the potency of actinomycetes. It is a fast, easy method with tangible results. This test was conducted to determine the inhibitory activity of actinomycetes against pathogenic bacteria, namely Escherichia coli and Staphylococcus aureus. This study aims to isolate, identify, and determine the antibacterial potential of actinomycetes from mangrove sediment.

MATERIALS AND METHODS

Study area

Samples of mangrove sediment were taken in December 2018, located in the Tanjung Api-Api mangrove area (Latitude 2°22’17.05” S, Longitude 104°48’19.74” E) in South Sumatra, Indonesia. It is one of the most important coastal mangroves within the South Sumatra Province. Since 2004, this area has been used as a domestic port with busy shipping activities.
Sampling and Actinomycetes isolation

Sediment samples were taken from the mangrove sediment around the root of Avicennia marina using a pipe with a diameter of four inches at a depth of 0 to 25 cm. About 500 g of the samples were collected and placed in a plastic bag and then stored in a cool box. Actinomycetes from mangrove sediment were isolated based on the method by Dede et al. (2020) and Kavitha and Vimala (2020). Samples were serially diluted. Actinomycetes isolates were cultured on Starch Casein Agar (SCA) medium with a composition of 10 g of soluble starch, 4 g of yeast extract, and 16 g of agar per 1 L of dH2O. Samples were incubated at 28°C for seven days.

Morphological and physiological characterization

Morphological characters of actinomycetes were observed using a microscope. It includes colony characteristics, hyphal type, and vegetative hyphal growth. Physiological characterization was carried out using several biochemical tests. It includes catalase test, motility test, indole production test, carbohydrate fermentation, TSIA test, Simmons citrate test, Methyl Red test, Voges-Proskauer test, MIO test, LIA test, urease and gelatin test. Identification of actinomycetes refers to Bergey's Manual Determinative of Bacteriology (Goodfellow et al. 2012).

Antagonists test of actinomycetes isolates against pathogenic bacteria

The antibacterial potential of actinomycetes was carried out by an antagonistic test against Escherichia coli and Staphylococcus aureus. This method referred to (He et al. 2020; Loqman et al. 2009; Patil et al. 2001; Remya et al. 2008; You et al. 2005). The inhibition zone was measured twice at 24 h and 48 h, and the average inhibition zone was estimated based on the minimum diameter and added to the maximum diameter.

RESULTS AND DISCUSSION

Morphological and physiological characteristics of Actinomycetes

There were ten isolates of Actinomycetes bacteria successfully isolated from mangrove sediments in Tanjung Api-Api water (Figure 1). They are grouped into eight bacterial genera based on their macroscopic, microscopic, and biochemical characteristics. There are three isolates (H8, H11, and H12) identified as the genus Streptomyces.

Morphologically, the ten isolates had different characteristics in shape, size, elevation, color, surface, and margin. The shapes of isolates are generally circular and irregular; only one is filamentous. The sizes of isolates are medium and large, with convex and flat elevations. The colors of the cells are white and yellow, with uneven and evenly margins. All isolates are motile gram-positive, aerobics, and facultative anaerobes. Physiologically, the isolates showed generally positive reactions to sugars (Table 1).

Eight genera of actinomycetes from mangrove sediment samples are as follows: Oerskovia H1, Micrococcus H2, Nocardia H3, Sporichthya H5, Corynebacterium H6, Jonesia H7, Actinomyces H10, and Streptomyces H8, H11, H12. The genus Streptomyces was identified to be more dominant than others. However, the morphological and physiological characteristics of the three isolates differed slightly. The cell surfaces of H8 and H11 were characterized by a smooth, while H12 was rough. The cell margin of H8 was even, while H11 and H12 were uneven. The cell color of H8 and H12 was white, while that of H11 was yellow. Several differences were also found in the biochemical characteristics of the three isolates. It indicates that the three Streptomyces isolates are thought to be different species.

Antibacterial potential of actinomycetes isolates

The inhibition zone of actinomycetes isolates collected from mangrove sediments had high variation depending on the bacteria tested and the time of measurement (24 h and 48 h). The number of isolates that inhibited the growth of Escherichia coli was greater than Staphylococcus aureus (Table 2).

Based on the inhibition zone (Table 2), there are five isolates have very strong and strong inhibitory activity against E. coli, i.e., Genus Nocardia H3 (27.81 mm ± 1.39), Actinomycetes H10 (27.75 mm ± 2.48), Corynebacterium H6 (27.69 mm ± 2.39), Micrococcus H2 (18.55 mm ± 2.44), and Streptomyces H8 (17.92 mm ± 2.70). Two isolates had potent inhibition against S. aureus, i.e., Genus Streptomyces H8 (24.83 mm ± 2.08) and Actinomycetes H10 (16.06 mm ± 2.49).

Figure 1. Inhibition zone of actinomycetes isolates against Escherichia coli and Staphylococcus aureus.
| Characteristics | H1     | H2     | H3     | H4     | H5     | H6     | H7     | H8     | H9     | H10    | H11    | H12    |
|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Shape           | filamentous | circular | irregular | circular | irregular | filamentous | filamentous | filamentous | filamentous | filamentous | filamentous | filamentous |
| Size            | large  | medium | large  | medium | medium | medium | medium | medium | medium | medium | medium | medium |
| Elevation       | flat   | convex | flat   | convex | convex | flat   | convex | convex | convex | convex | convex | convex |
| Surface         | smooth | smooth | smooth | smooth | smooth | smooth | smooth | smooth | smooth | smooth | smooth | rough |
| Margene         | uneven | evenly | uneven | uneven | evenly | uneven | uneven | uneven | uneven | uneven | uneven | uneven |
| Color           | white  | yellow | yellow | white  | yellow | cream yellow | white | cream yellow | yellow | white | white | white |
| Cell shape      | bacillus | bacillus | bacillus | bacillus | bacillus | bacillus | bacillus | bacillus | bacillus | bacillus | bacillus | bacillus |
| Motility        | -      | +      | +      | +      | +      | -      | -      | -      | +      | -      | +      | +      |
| Gram            | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      |
| Oxygen          | facultative anaerobic | facultative anaerobic | aerobe | facultative anaerobic | aerobe | facultative anaerobic | aerobe | facultative anaerobic | aerobe | aerobe | aerobe | aerobe |
| Gelatin         | -      | -      | +      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Indole          | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Urea            | -      | -      | -      | -      | -      | +      | +      | +      | +      | +      | +      | +      |
| Citrate         | -      | -      | -      | -      | -      | +      | +      | +      | -      | +      | +      | +      |
| Lysine iron agar| +      | +      | -      | +      | +      | +      | +      | -      | +      | +      | +      | +      |
| Mio             | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| NaCl 4%         | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      |
| Methyl red      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Voges-Proskauer | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      |
| TSIA            | acid   | catalyst | acid | acid | acid | catalyst | catalyst | catalyst | catalyst | catalyst | catalyst | catalyst |
| Catalase        | +      | +      | +      | -      | -      | +      | +      | +      | +      | +      | +      | +      |
| Oxidase         | +      | +      | +      | -      | -      | -      | +      | +      | +      | +      | +      | +      |
| Glucose         | +      | +      | +      | +      | -      | +      | +      | +      | +      | +      | +      | +      |
| Sucrose         | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      |
| Lactose         | -      | -      | -      | -      | -      | -      | +      | -      | -      | -      | -      | -      |
| Esculin         | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      | +      |
| Arabinose       | -      | -      | -      | -      | -      | -      | +      | -      | +      | +      | +      | +      |
| Cellobiose      | +      | +      | -      | -      | -      | -      | +      | +      | +      | +      | +      | +      |
| Galactose       | -      | +      | -      | -      | -      | +      | -      | -      | +      | +      | +      | +      |
| Fructose        | +      | +      | +      | +      | -      | +      | +      | +      | +      | +      | +      | +      |
| Maltose         | -      | +      | -      | +      | -      | +      | +      | +      | +      | +      | +      | +      |
| Melibiose       | -      | +      | -      | +      | -      | +      | -      | +      | +      | +      | +      | +      |
| Xylose          | -      | +      | -      | +      | -      | +      | -      | +      | +      | +      | +      | +      |
| Trehalose       | -      | +      | -      | +      | -      | +      | +      | +      | +      | +      | +      | +      |
| Raffinose       | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Rhamnose        | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Genus           | Oreskovic | Micrococcus | Nocardia | Sporichthya | Corynebacterium | Jonesia | Streptomyces | Actinomyces | Streptomyces | Streptomyces | Streptomyces | Streptomyces |

Table 1. Characteristics of Actinomycetes isolated from mangrove sediment.
The inhibitory zone is presumably related to the production of active antibacterial compounds by these isolates (Ahmad et al. 2019; Al-Farraj et al. 2020; Fahmy 2020; Sapkota et al. 2020). Several previous studies showed that actinomycetes have good antibacterial activity. For example, Nocardia from Indian mangrove ecosystems (Manikkam et al. 2019), Actinomyces from Nipah mangrove sediment (Yanti et al. 2020), Corynebacterium the sediment of Valparaíso bay, Chile (Claverías et al. 2019), Micrococcus from seawater (Kumari et al. 2020), and Streptomyces from mangrove soil sediment (Al-Dhabi et al. 2019; Al-Farraj et al. 2020; Fahmy 2020; Kripa et al. 2020; Sabido et al. 2020).

Five isolates showed more potent antibacterial activity against E. coli than S. aureus. They were more effective in inhibiting gram-negative bacteria than gram-positive bacteria. Gram-positive bacteria have a thicker cell membrane than gram-negative bacteria (Christofferson et al. 2020). Therefore, the active antibacterial compounds might be easier to penetrate the membrane cell of gram-negative bacteria. Antibacterial activity is also influenced by the method, type, and level of resistance of the tested microbes.

In conclusion, total of ten actinomycetes bacteria isolated from the mangrove sediments in Tanjung Api-Api, South Sumatra, and was grouped into eight genera, i.e., Oerskovia H1, Micrococcus H2, Nocardia H3, Sporichthya H5, Corynebacterium H6, Jonesia H7, Actinomyces H10, and Streptomyces H8, H11, H12. Five isolates showed very strong antibacterial activity, namely, Micrococcus H2, Nocardia H3, Corynebacterium H6, Streptomyces H8, and Actinomyces H10 against gram-negative bacteria. Their antibacterial potential is more likely to inhibit gram-negative than gram-positive bacteria. Actinomycetes isolated from mangrove sediment have the potential as natural medicine.

**ACKNOWLEDGEMENTS**

We would like to thank the head of the Marine Bioecology Laboratory, Faculty of Mathematics and
Natural Sciences, Sriwijaya University, Indonesia for supporting facilities in this research.

REFERENCES

Abdul ZAZ, Malek NA, Zainuddin Z, et al. 2016. Selective isolation and antagonistic activity of actinomycetes from mangrove forest of Pahang, Malaysia. Front Life Sci 9 (1): 24-31. DOI: 10.1080/21553769.2015.1051244.

Ahmad I, Althubiani AS, Dar MS, Qais FA, Abulreesh HH, Bamaga MA, Al-Ghamdi SB, Alshehri F. 2019. Actinomycetes as continued source of new antibacterial leads. In: Antibacterial Drug Discovery to Combat MDR. Springer Nature Singapore, Singapore.

Al-Dhabi NA, Esmai GA, Ghilan AKM, et al. 2020. Chemical constituents of Streptomyces sp. strain Al-Dhabi-97 isolated from the marine region of Saudi Arabia with antibacterial and anticancer properties. J Infect Pub Heal 13 (2): 235-243. DOI: 10.1016/j.jiph.2019.09.004.

Al-Dhabi NA, Ghilan A-KM, Esmai GA, et al. 2019. Bioactivity assessment of the Saudi Arabian Marine Streptomyces sp. Al-Dhabi-90, metabolic profiling and its in vitro inhibitory property against multidrug-resistant and extended-spectrum beta-lactamase clinical bacterial pathogens. J Infect Pub Heal 12 (4): 549-556. DOI: 10.1016/j.jiph.2019.01.065.

Al-Farraj DA, Varghese R, Vagvolgyi C, et al. 2020. Antibiotics production in optimized culture condition using low cost substrates from Streptomyces sp. AS4 isolated from mangrove soil sediment. J King Saud Univ Sci 32 (2): 1528-1535. DOI: 10.1016/j.jsus.2019.12.008.

Arifiyanto A, Surtiningsih T, Ni'matuzahroh, et al. 2020. Antimicrobial properties of peptidoglycan of Gram-positive bacteria. J Infect Pub Heal 13 (7): 3072-3080. DOI: 10.9598/0974-360X.2020.00545.4.

Fahmy NM. 2020. Isolation and characterization of Streptomyces sp. NMF76 with potential antimicrobial activity from mangrove sediment, Red Sea, Egypt. Egypt J Aqua Biol Fish 24 (6): 479-495. DOI: 10.1016/j.eijkabf.2020.117578.

Gacem MA, Khelif AOEH, Boujdema B, et al. 2020. Antimicrobial and antioxidant effects of a forest actinobacterium v 002 as new producer of Spectinactin, Undecylenodigrosin and Metacycloprodigiosin. Curr Microbiol 77 (10): 2575-2583.

Gong Y, Chen LJ, Pan SY, et al. 2020. Antifungal potential evaluation and alleviation of salt stress in tomato seedlings by a halotolerant plant growth-promoting actinomycete Streptomyces sp. KLBPMP5084. Rhizosphere 16: 100026. DOI: 10.1016/j.rhisph.2020.100026.

Goodfellow M, Kämpfer P, Busse HJ, et al. 2012. Bergey's manual of systematic bacteriology: volume five the actinobacteria, Part A. Springer, New York.

Hamed AA, Kabary H, Khedr M, et al. 2020. Antibiofilm, antimicrobial and cytotoxic activity of extracellular green–synthesized silver nanoparticles by two marine-derived actinomycetes. RSC Adv 10 (17): 10361-10367. DOI: 10.1039/C9RA11021F.

Hassan SED, Salem SS, Fouda A, et al. 2018. New approach for antimicrobial activity and bio-control of various pathogens by biosynthesized copper nanoparticles using endophytic actinomycetes. J Radiat Res Appl Sci 11 (3): 262-270. DOI: 10.1016/j.jrras.2018.05.003.

He H, Hao X, Zhou W, et al. 2020. Identification of antimicrobial metabolites produced by a potential biocontrol Actinomycete strain A217. J Appl Microbiol 128 (4): 1143-1152. DOI: 10.1111/jam.15458.

Imamsyah A, Arthana IW, Astarini IA. 2020. The influence of physicochemical environment on the distribution and abundance of mangrove gastropods in Ngrurah Rai Forest Park Bali, Indonesia. Biodiversitas 21: 3178-3188 DOI: 10.13057/biodiv/120740.

Kavita S, Vimala RJ. 2020. Screening of Marine Actinomycetes for inhibitory activity against biofilm-forming bacteria. J Env Biol 41 (5): 995-1002. DOI: 10.22438/jeb/41/SRN-1215.

Kripa N, Reyanthan P, Beevi MR et al. 2020. Isolation of Streptomyces spp. with bioprospecting potential from Mangrove Regions of Ponnani, Kerala, India. J Aqua Biol Fish 8: 1-6.

Kumar P, Kundu A, Kumar M, et al. 2019. Exploitation of potential bioactive compounds from two soil derived actinomycetes, Streptomyces sp. strain 196 and RI. 24. Microbiol Res 229: 126312. DOI: 10.1016/j.micres.2019.126312.

Kumar P, Ling C, Zhou Z, et al. 2020. Chemical diversity of metabolites and antibacterial potential of actinomycetes associated with marine invertebrates from intertidal regions of Daya Bay and Nansha Islands. Microbiology 89 (4): 483-492.

Kumari KS, Shuvakrishna P, Al-Attar AM, et al. 2020. Antibacterial and cytotoxicity activities of bioactive compounds from Micrococcus species OUS9 isolated from seawater. J King Saud Univ Sci 32 (6): 2818-2825. DOI: 10.1016/j.jsus.2020.07.003.

Lee LH, Zainal N, Azman AS et al. 2014. Diversity and antimicrobial activities of actinobacteria isolated from tropical mangrove sediments in Malaysia. Sci World J 2014: 1-14. DOI: 10.1155/2014/698178.

Lekanaaksakul K, Thamchaiperox A. 2018. Potential anti-biofilm producing marine actinomycetes isolated from sea sediments in Thailand. Agri Nat Res, 52 (3): 228-233. DOI: 10.1016/j.ijares.2018.09.003.

Logman S, Barka EA, Clément C et al. 2009. Antagonistic actinomycetes from Moroccan soil to control the grapevine gray mold. World J Microbiol Biotechnol 25 (1): 81-91.

Mahapatra GP, Raman S, Nayak S et al. 2019. Metagenomics approaches in discovery and development of new bioactive compounds from marine actinomycetes. Curr Microbiol 77: 645-656.

Manikkam R, Pati P, Thangavel S et al. 2019. Distribution and bioprospecting potential of actinobacteria from Indian mangrove ecosystems. In: Microbial Diversity in Ecosystem Sustainability and Biotechnological Applications. Springer, New York.

Matthew RO, Ire F, Peterside NJF. 2020. Screening of actinomycetes from turmeric (Curcuma longa L.) and ginger (Zingiber officinale) rhizosphere for antifungal activity. J Adv Microbiol 20 (2): 18-28. DOI: 10.9734/jamb/2020/v20i230214.

Patil R, Jeyasekaran G, Shanmugam S et al. 2001. Control of bacterial pathogens, associated with fish diseases, by antagonistic marine actinomycetes isolated from marine sediments. Ind J Mar Sci 30 (7): 176-179.

Perser S, Tnenfeld F, Hagerdal BH. 1991. Fungal cellulolytic enzyme production: A review. Proc Biochem 26 (2): 65-74. DOI: 10.1016/0094-5766(91)90019-4.

SIREGAR et al. – Relationship between interferon-tau level (IFN-τ) and Neodipsas flavida Fossil Remains at Sede Boker, Israel. Geosciences 10: 360. DOI: 10.3390/geosciences10030360.

Thiria L, Vincent P, El Alami K, et al. 2018. Diversity and antimicrobial activity of marine actinomycetes isolated from the Red Sea, Egypt. Egypt J Aqua Biol Fish 24 (6): 769-780. DOI: 10.1016/j.eijkabf.2020.117578.
Reef R, Feller IC, Lovelock CE. 2010. Nutrition of mangroves. Tree Physiol 30 (9): 1148-1160. DOI: 10.1093/treephys/tpq048.

Remya M, Vijayakumar R. 2008. Isolation and characterization of marine antagonistic actinomycetes from the West coast of India. Med Biol 15 (1): 13-19.

Sabido EM, Tenebro CP, Suarez AFL, et al. 2020. Marine sediment-derived Streptomyces strain produces angucycline antibiotics against multidrug-resistant Staphylococcus aureus Harboring SCCmec type I gene. J Mar Sci Eng 8 (10): 734. DOI: 10.3390/jmse8100734.

Sapkota A, Thapa A, Budhathoki A, et al. 2020. Isolation, characterization, and screening of antimicrobial-producing actinomycetes from soil samples. Int J Microbiol 2020: 1-7. DOI: 10.1155/2020/2716584.

Shaala LA, Youssef DT, Alzuhabi TA, et al. 2020. Antimicrobial Chlorinated 3-Phenylpropanoic acid derivatives from the Red Sea marine actinomycete Streptomyces coelicolor LY001. Mar. Drugs 18 (9): 450. DOI: 10.3390/md18090450.

Shah AM, Shakeel u R, Hussain A, et al. 2017. Antimicrobial investigation of selected soil actinomycetes isolated from unexplored regions of Kashmir Himalayas, India. Microbial Path 110: 93-99. DOI: 10.1016/j.micpath.2017.06.017.

Shamkh YI, El Shamy AA, Gaber Y, et al. 2020. Actinomycetes from the Red Sea sponge Coscinodera mathiesii: isolation, diversity, and potential for bioactive compounds discovery. Microorganisms 8 (5): 783. DOI: 10.3390/microorganisms8050783.

Suresh RS, Younis EM, Fredimoses MJ. 2020. Isolation and molecular characterization of novel Streptomyces sp. ACT2 from marine mangrove sediments with antidermatophytic potentials. J King Saud Univ Sci 32 (3): 1902-1909. DOI: 10.1016/j.jksus.2020.01.020.

Talpur MKA, Qazi MA, Phulpoto AH, et al. 2020. Bioprospecting actinobacterial diversity antagonistic to multidrug-resistant bacteria from untapped soil resources of Kotdiji, Pakistan. Biologia 75 (1): 129-138.

Tistechok S, Skvortsova M, Luzhetskyy A, et al. 2019. Antagonistic and plant growth promoting properties of actinomycetes from rhizosphere Deschampsia antarctica É. Desv. (Galinédez Island, Antarctica). Ukraine Antarctic J 1 (18): 140. DOI: 10.33275/1727-7485.

Waithaka PN, Gathuru EM, Gitaha BM, et al. 2019. Microbial degradation of maize waste materials using actinomycetes isolated from Egerton University Soils, Njoro in Kenya. Intl Res J Biol Sci 1 (1): 31-36.

Yanti A, Setyawati T, Kurniatiuadih R. 2020. Composition and characterization of actinomycetes isolated from Nipah mangrove sediment, gastrointestinal and fecal pellets of Nipah worm (Namalycastis rhodhocorde). IOP Conf Ser Earth Environ Sci 550: 012003. DOI: 10.1088/1755-1315/550/1/012003.

You JL, Cao LX, Liu GF, et al. 2005. Isolation and characterization of actinomycetes antagonistic to pathogenic Vibrio spp. from nearshore marine sediments. World J Microbiol Biotech 21 (5): 679-682.