

## REFERENCES

- Agler, M.T., Ruhe, J., Kroll, S., Morhenn, C., Kim, S-T., Weigel, D., & Kemen, E.M. 2016. Microbial hub taxa link host and abiotic factors to plant microbiome variation. *PLoS Biol.* 14 (1): e1002352. DOI: 10.1371/journal.pbio.1002352.
- Ahmad, F. 2021. Genetics and diversity of Indonesian bananas. PhD Thesis. Wageningen University. Wageningen the Netherlands.
- Alijani, Z., Amini, J., Ashengroph, M., & Bahramnejad, B. 2022. Antifungal activity of *Serratia rubidaea* Mar61-01 purified prodigiosin against *Colletotrichum nymphaeae*, the causal agent of strawberry anthracnose. *J. Plant Growth Regul.* 41: 585–595. DOI: 10.1007/s00344-021-10323-4.
- Alijani, Z., Amini, J., Karimi, K., & Pertot, I. 2023. Characterization of the mechanism of action of *Serratia rubidaea* Mar61-01 against *Botrytis cinerea* in strawberries. *Plants.* 12: 154. DOI: 10.3390/PLANTS12010154.
- Amir, H. & Alabouvette, C. 1993. Involvement of soil abiotic factors in the mechanism of soil suppressiveness to *Fusarium* wilts. *Soil Biol Biochem.* 25(2):157–64. DOI:10.1016/0038-0717(93)90022-4.
- Anshari, W.A., Kumar, M., Krishna, R., Singh, A., Zeyad, M.T., Tiwari, P., Kumar, S.C., Chakdar, H., & Srivastava, A.K. 2024. Influence of rice-wheat and sugarcane-wheat rotations on microbial diversity and plant growth promoting bacteria: Insight from high-throughput sequencing and soil analysis. *Microb Res.* 278: 127533. DOI: 10.1016/j.micres.2023.127533.
- Ariadi, B.Y., Relawati, R., Agustina Y., Haryanto, L.I., & Kamarudin, M.F. 2024. The promising prospect of banana production and marketing in Indonesia. *SOCA.* 18(1): 59-76. DOI: 10.24843/SOCA.2024.V18.I01.P05.
- Armour, J. 2018. Nutrient Management Plan for the Banana Industry (of North Queensland). [https://abgc.org.au/wp-content/uploads/2018/04/Ban-NMP\\_submit-R1.pdf](https://abgc.org.au/wp-content/uploads/2018/04/Ban-NMP_submit-R1.pdf). Accessed on 23 October 2023.
- Atim, M., Beed, F., Tusiime, G., Tripathi, L., & van Asten, P. 2013. High potassium, calcium, and nitrogen application reduce susceptibility to banana *Xanthomonas* wilt caused by *Xanthomonas campestris* pv. *Musacearum*. *Plant Dis.* 97: 123-130. DOI: 10.1094/PDIS-12-0646-RE.
- Atmoko, D.D., Titisari, A.D., & Idrus, A. 2018. Geochemical characteristics of limestone of Wonosari-Punung formation, Gunungkidul Regency, Yogyakarta, Indonesia. *IJOG.* 5(2): 179-197. DOI: 10.17014/ijog.5.2.179-197.
- Ausubel, F.M., R. Brent., R.E. Kingston., D.D. Moore., J.G. Seidman., J.A.Smith., & K. Struhl. 1995. *Short Protocols in Molecular Biology*. 3rd Edition. John Wiley & Sons Inc. California, USA.



UNIVERSITAS  
GADJAH MADA

**Analysis of soil bacteria promoting banana to tolerate fusarium wilt disease (*Fusarium oxysporum* f.sp. *ubense* TR4) in the Special Province of Yogyakarta**

Irianti Kurniasari, Dr. Ir. Arif Wibowo, M.Agr.Sc; Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc; Anthony B Pattison, Ph.D  
Universitas Gadjah Mada, 2024 | Diunduh dari <http://etd.repository.ugm.ac.id/>

- Badri, D.V., & Vivanco, J.M. 2009. Regulation and function of root exudates. *Plant Cell Environ.* 32(6): 666-681. DOI: 10.1111/j.1365-3040.2009.01926.x.
- Baldock, J., & Nelson, P. 2000. Soil organic matter. In: Sumner, M.E. (eds) *Handbook of Soil Science*. CRC Press. USA.
- Banarjee, S., Schlaeppli, K., & van der Heijden, M.G.A. 2018. Keystone taxa as drivers of microbiome structure and functioning. *Nat Rev Microbiol.* 16 (9): 567-576. DOI: 10.1038/s41579-018-0024-1.
- Baum, C., Eichler-Loberman, B., & Hrynkiewicz, K. 2015. Impact of organic amendments on the suppression of *Fusarium* wilt. In: Meghvansi, M.K., Varma, A. (eds). *Organic amendments and soil suppressiveness in plant disease management*. Springer international publishing, Cham, 353-362.
- Birt, H.W.G., Pattison, A.B., Skarshewski, A., Daniells, J., Raghavendra, A., & Dennis, P.G. 2022. The core bacterial microbiome of banana (*Musa* spp.). *Environ Microbiome.* 17 (1): 46. DOI: 10.1186/s40793-022-00442-0.
- Bolyen, E., Rideout, J.R., Dillon, M.R., et al. 2019. Reproducible, interactive, scalable and extensible microbiome data science using QIIME 2. *Nat Biotechnol.* 37 (8): 852-857. DOI: 10.1038/s41587-019-0209-9.
- Boukhalfa, H., & Crumbliss, A.I. 2002. Chemical aspects of siderophore mediated iron transport. *Biometals.* 15(4): 325-339. DOI: 10.1023/a:1020218608266.
- Boukhatem, Z.F., Merabet, C., & Tsaki, H. 2022. Plant growth promoting actinobacteria, the most promising candidates as bioinoculant? *Front Agron.* 4: 849911. DOI: 10.3389/fagro.2022.849911.
- Bowen, A., Orr, R., Mcbeath, A., Pattison, A., & Nelson, P. 2019. Suppressiveness or conduciveness to *Fusarium* wilt of bananas differs between key Australian soils. *Soil Res.* 57:158-65. DOI: 10.1071/SR18159.
- Broders, K.D., Wallhed, M.W., Austin, G.D., Lipps, P.E., Paul, P.A., Mullen, R.W., & Dorrance, A.E. 2009. Association of soil chemical and physical properties with *Phytium* species diversity, community composition, and disease incidence. *Ecol Epidemiol.* 99(8): 957-967. DOI: 10.1094/PHYTO-99-8-0957.
- Brown & Lemon. 2023. Cations and Cation Exchange Capacity. <<https://www.soilquality.org.au/factsheets/cation-exchange-capacity>>. Accessed on 23 October 2023.
- Bubici, G., M. Kaushal., M.I. Prigigallo., C.G.L. Cabanas., & J.M. Blanco. 2019. Biological control agents against *Fusarium* wilt of banana. *Front Microbiol.* 10(616): 1-33. DOI: 10.3389/FMICB.2019.00616.
- Buddenhagen, I. 2009. Understanding strain diversity in *Fusarium oxysporum* f. sp. *ubense* and history of introduction of "Tropical Race 4" to better manage banana production. *Acta Hort.* 828: 193-204. DOI: 17660/aCTAhORTIC.2009.828.19.



- Campos-Soriano, L., Bundó, M., Bach-Pages, M., Chiang, S-F., Chiou, T-J., & Segundo, B.S. 2020. Phosphate excess increases susceptibility to pathogen infection in rice. *Mol Plant Pathol.* 21 (4): 555-570. DOI: 10.1111/mpp/12916.
- Danicic, A., Vucic, N., Ksapovic, S., & Pajic, V. 2018. Taxonomic Profiling of metagenomics samples. *Genomics.* <https://www.sevenbridges.com/taxonomic-profiling-of-metagenomics-samples/>. Accesses on Juni 2024.
- Deltour, P., Franca, S.C., Pereira, O.L., Cardoso, I., De Neve, S., Debode, J., & Hofte, M. 2017. Disease suppressiveness to *Fusarium* wilt of banana in an agroforestry system: influence of soil characteristics and plant community. *Agric Ecosyst Environ.* 239: 173-181. DOI: 10.1016/j.agee.2017.01.018.
- Dhungana, S., & Crumbliss, A.I. 2005. Coordination chemistry and redox processes in siderophore-mediated iron transport. *Geomicrobial J.* 22(3-4): 87-98. DOI: 10.1080/01490450590945870.
- Di Benedetto, N.A., Corbo, M.R., Campaniello, D., Cataldi, M.P., Bevilacqua, A., Sinigaglia, M., & Flagella, Z. 2017. The role plant growth promoting bacteria in improving nitrogen use efficiency for sustainable crop production: A focus on wheat. *AIMS Microbiol.* 3 (3): 413-434. DOI: 10.3934/microbial.2017.3.413.
- Dita, M., Barquero, M., Heck, D., Mizubuti, E.S.G., & Staver, C.P. 2018. *Fusarium* wilt of banana: current knowledge on epidemiology and research needs toward sustainable disease management. *Front. Plant.Sci.* 9(1466): 1-21. DOI: 10.3389/FPLS.2018.01468.
- Dong, X., Xiong, Y., Ling, N., Shen, Q., & Guo, S. 2014. Fusaric acid accelerates the senescence of leaf in banana when by *Fusarium*. *World J Microbiol Biotechnol.* 30(4): 1399-1408. DOI: 10.1007/s11274-013-1564-1
- Dong, X., Wang, M., Ling, N., Shen, Q., & Guo, S. 2016. Effects of iron and boron combinations on the suppression of *Fusarium* wilt in banana. *Sci Rep.* 6:38944. DOI: 10.1038/srep38944.
- Dorel, M. 1993. Banana development in an andosol in Guadeloupe: Effect of soil compaction. *Fruits*, 48: 83–88. PASCAL INIST identifier 4110519.
- Durán, P., Thiergart, T., Garrido-Oter, R., Agler, M., Kemen, E., Schulze-Lefert, P., & Hacquard, S. 2018. Microbial interkingdom interactions in root promote *Arabidopsis* survival. *Cell.* 175 (4): 973-983e14. DOI: 10.1016/j.cell.2018.10.020. DOI: 10.3389/fpls
- Effendi, Y., Pambudi, A., & Pancoro, A. 2019. Metagenomic analysis of *Fusarium oxysporum* f.sp. *cubense*-infected soil in banana plantation, Sukabumi, Indonesia. *Biodiversitas.* 20(7): 1939-1945. DOI: 10.13057/biodiv/d200721.
- Egas, C., Barroso, C., Froufe, H.J.C., Pacheco, J., Albuquerque, L., & da Costa, M.S. 2014. Complete genome sequence of the radiation-resistant bacterium *Rubrobacter radiotolerans* RSPS-4. *Stand Genomic Sci.* 9 (3): 1062-1075. DOI: 10.4056/sigs.5661021.
- Fan, H., He, P., Xu, S., Li, S., Wang, Y., Zhang, W., Li, X., Shang, H., Zeng, L., & Zheng, S-J. 2023. Banana disease-suppressive soil drives *Bacillus* assembled to defense *Fusarium* wilt of banana. *Front Microbiol.* 14: 1211301. DOI: 10.3389/fmicb.2023.1211301.

- Fang, X., You, M.P., & Barbetti, M. J. 2012. Reduced severity and impact of Fusarium wilt on strawberry by manipulation of soil pH, soil organic amendments and crop rotation. *Eur J Plant Pathol.* 134: 619-629. DOI: 10.1007/s10658-012-0042-1
- FAOSTAT [Food and Agriculture Organization of the United Nations]. 2024. Crop production data for multiple countries including area harvested, yield, and production for bananas in 2021. [www.fao.org/faostat/en/#data/QV](http://www.fao.org/faostat/en/#data/QV). Accessed on 24 February 2024.
- Friedman, J., & Alm, E.J. 2012. Inferring correlation networks from genomic survey data. *PLoS Comput Biol.* 8 (9): e1002687. DOI: 10.1371/journal.pcbi.1002687.
- Fourie, G., Steenkamp, E.T, Ploetz, R.C., Gordon, T.R., & Viljoen, A. 2011. Current status of the taxonomic position of *Fusarium oxysporum* formae special *cubense* within the *Fusarium oxysporum* complex. *Infect Genet Evol.* 11: 533–542. DOI: 10.1016/J.meegid.2011.01.012.
- Galloway-Pena & Hanson. 2020. Tools for analysis of the microbiome. *Dig Dis Sci.* 65(3): 674-685. DOI: 10.1007/s10620-020-06091-y.
- Garcia-Bastidas, F. 2022. *Fusarium oxysporum* f.sp. *cubense* Tropical race 4 (Foc TR4). CABI COMPENDIUM. <https://cabidigitallibrary.org>. Accessed on 5 March 2024.
- Gatiboni, L. 2022. Soils and Plant Nutrients, Chapter 1. In: Moore, K.A., & Bradley, L.K. (eds). *North Carolina Extension Gardener Handbook*, 2nd ed. NC State Extension, Raleigh, NC. <<https://content.ces.ncsu.edu/extension-gardener-handbook/1-soils-and-plant-nutrients>>. Accessed on 23 October 2023.
- Gu, Y., Li, B., Zhong, X., Liu, C., & Ma, B. 2022. Bacterial community composition and function in a tropical municipal wastewater treatment plant. *Water.* 14 (10): 1537. DOI: 10.3390/w14101537.
- Guo, B., Zhang, L., Sun, H., Gao, M., Yu, N., Zhang, Q., Mou, A., & Liu, Y. 2022. Microbial co-occurrence network topological properties link with reactor parameters and reveal importance of low-abundance genera. *Npj Biofilms Microbi.* 8:3. DOI: 10.1038/S41522-021-00263-y.
- Guimarães, G.G.F., Cantú, R.R., Scherer, R.F., Beltrame, A.B., & de Haro, M.M. 2020. Banana crop nutrition: Insights into different nutrient sources and soil fertilizer application strategies. *Rev Bras Cienc Solo.* 44: e0190104. DOI: 10.36783/18069657rbcs20190104.
- Gökbulak, F., & Özcan, M. 2008. Hydro-physical properties of soils developed from different parent materials. *Geoderma.* 145 (3-4): 376-380. DOI: 10.1016/j.Geoderma.2008.04.006.
- Hakim, S., Naqqash, T., Nawaz, M.S., Laraib, I., Siddique, M.J., Zia, R., Mirza, M.S., & Imran, A. 2021. Rhizosphere engineering with plant growth-promoting microorganisms for agriculture and ecological sustainability. *Front Sustain Food Syst.* 5: 617157. DOI: 10.3389/fsufs.2021.617157.
- Ham, S.H., Yoon, A.R., Oh, H.E., & Park, Y.G. 2022. Plant growth-promoting microorganism *Pseudarthrobacter* sp. NIBRBAC000502770 enhances the growth and flavonoid content of *Geum alepnicum*. *Microorganisms.* 10 (6): 1241. DOI: 10.3390/microorganisms10061241.

- Hermanto, C., Sutanto, A., Jumjunidang, Edison, H.S., Daniells, J.W., O'Neill, W.T., Sinohin, V.G.O., Molina, A.B., & Taylor, P. 2011. Incidence and distribution of *Fusarium* wilt disease of banana in Indonesia. *Acta Hort.* 897: 313-322. DOI: 10.17660/ActaHortic.2011.897.43.
- Hidayati & Suhartini. 2018. Analisis daya saing ekspor pisang (*Musa paradiaca* L.) Indonesia di pasar asean dalam menghadapi masyarakat ekonomi asean (MEA). *JEPA*. 2(4): 267-278. DOI: 10.21776/ub.jepa.2018.002.04.2.
- Hill, G.T., Mitkowski, N.A., Aldrich-Wolfe, L., Emele, L.R., Jurkonie, D.D., Ficke, A., Maldonado-Ramirez, S., Lynch, S.T., Nelson, E.B. 2000. Methods for assessing the composition and diversity of soil microbial communities. *Appl Soil Ecol.* 15(1): 25-36. DOI: 10.1016/S0929-1393(00)00069-X.
- Hou, M., Zhao, X., Wang, Y., Lu, X., Chen, Y., Jiao, X., & Sui, Y. 2023. Pedogenesis of typical zonal soil drives belowground bacterial communities of arable land in the Northeast China Plain *Sci Rep.* 13 (1): 14555. DOI: 10.1038/S41598-023-41401-0.
- Jerez, C.A. 2009. Metal extraction and biomining. In: Schaechter, M. (eds). *Encyclopedia of Microbial* (Third Edition). Academic Press, San Diego, USA.
- Jia, M., Sun, X., Chen, M., Liu, S., Zhou, J., & Peng, X. 2022. Dechiperling the microbial diversity associated with healthy and wilted *Paeonia suffruticosa* rhizosphere soil. *Front Microbiol.* 13: 967601. DOI: 10.3389/fmicb.2022.967601.
- Johnson, L. 2008. Iron and siderophores in fungal-host interactions. *Mycol Res.* 112(2): 170-183. DOI: 10.1016/j.mycres.2001.11.012.
- Jumjunidang, Edison, Riska & C. Hermanto. 2012. Penyakit layu fusarium pada tanaman pisang di Provinsi NAD: sebaran dan identifikasi isolat berdasarkan analisis Vegetative Compatibility Group. *J Hort.* 22(2): 164-171. DOI: 10.21082/JHORT.V22N2.2012.P165-172.
- Jutono, J. Soedarsono., S. Hartadi., S. Kabirun., D. Suhadi., & Soesanto. 1980. *Pedoman Praktikum Mikrobiologi Umum (untuk Perguruan Tinggi)*. Departemen Mikrobiologi Fakultas Pertanian. Universitas Gadjah Mada. Yogyakarta.
- Kinkel, L.L., Bakker, M.G., & Schlatter, D.C. 2011. A coevolutionary framework for managing disease-suppressive soils. *Ann Rev Phytopathol.* 49: 47-67. DOI: 10.1146/annurev-phyto-072910-095232.
- Kress, W.J & Specht, C.D. 2006. The evolutionary and biogeographic origin and diversification of the tropical monocot order Zingiberales. *Aliso.* 22(1): 621-632.
- Kulshreshta, S., Rajput, N.S., & Penna, S. 2023. Microbial volatiles-mediated plant growth promotion and stress management in plants. In: Sharma, V., Salwan, R., Moliszewska, E., Ruano-Rosa, D., & Jedryczka, M. (eds). *The Chemical Dialogue Between Plants and Beneficial Microorganisms*. Academic Press, USA.
- Kusumandari, A. 2014. Soil erodibility of several types of green open space areas in Yogyakarta City, Indonesia. *Proceedings the 4<sup>th</sup> International Conference on a Sustainable Future for Human Security*. Kyoto University, Japan, 19-21 October 2013.

- Lahti, L., & Shetty, S. 2019. Microbiome R Package. Available online at: [www.microbiome.github.io](http://www.microbiome.github.io).
- Lilai, S.A., Kapinga, F.A., Nene, W.A., Mbaso, W.V., & Tibuhwa, D.D. 2021. Ecological factors influencing severity of chesew Fusarium wilt disease in Tanzania. *Res Plant Dis.* 27(2): 49-60. DOI: 10.5423/RPD.2021.27.2.49
- Luo, S., Wang, Z., & Xu, W. 2023. *Bacillus velezensis* WB invokes soil suppression of *Fusarium oxysporum* f.sp.niveum by inducing particular taxa. *Ann Agric Sci.* 68: 159-170. DOI: 10.1016/j.aos.2023.12.005.
- Lucaciu, R., Pelikan, C., Gerner, S.M., Zoutis, C., Kostlbacher, S., Marx, H., Herbold, C.W., Schmidt, H., & Rattei, T. 2019. A bioinformatics guide to plant microbiome analysis. *Front Plant Sci.* 10:1313. DOI: 10.3389/fpls.2019.01313.
- Ma, B., Wang, Y., Ye, S., Liu, S., Stirling, E., Gilbert, J.A., Faust, K., Knight, R., Jansson, J.K., Cardona, C., Röttgers, L., & Xu, J. 2020. Earth microbial co-occurrence network reveals interconnection pattern across microbiomes. *Microbiome.* 8(1): 82. DOI: 10.1186/s40168-020-00857-2.
- Ma, Y., Wang, J., Liu, Y., Wang, X., Zhang, B., Zhang, W., Chen, T., Liu, G., Xue, L., & Cui, X. 2023. *Nocardioides*: "Specialists" for hard to degrade pollutants in the environment. *Molecules.* 28(21): 7433. DOI: 10.3390/molecules28217433.
- Mak, C., Mohamed, A.A., Liew, K.W., & Ho, Y.W. 2004. Early screening technique for fusarium wilt resistance in banana Micropropagated plants. *In: Jain, S.M & R. Swennen (Eds). Proceedings of banana improvement: cellular, molecular biology, and induced mutations. Leuven Belgium. 24-28 September 2004. 219-227.*
- Maldonado Bonilla, L.D., Villarruel Ordaz, J.L., Calderón Oropeza, M.A., & Sánchez-Espinosa, A.C. 2018. Secreted in xylem (six) genes in *Fusarium oxysporum* f. sp. *ubense* and their potential acquisition by horizontal transfer. *Adv Biotechnol Microbiol.* 10: AIBM.MS.ID.555779. DOI: 10.19080/AIBM.2018.10.555779.
- Manna MC, Swarup A, Wanjari RH, Mishra B, and Shahi DK. 2007. Long-term fertilization, manure and liming effects on soil organic matter and crop yield. *Soil Tillage Res.* 94: 397-409. DOI: 10.1016/j.still.2006.08.013.
- Maquia, I.S.A., Fareleira, P., Castro, I.V.E., Soares, R., Brito, D.R.A., Mbanze, A.A., Chaúque, A., Máguas, C., Ezeokoli, O.T., Ribeiro, N.S., Marques, I., & Ribeiro-Barros, A.I. 2021. The nexus between fire and soil bacterial diversity in the African Miombo woodlands of niassa special reserve, Mozambique. *Microorganisms.* 9(8): 1562. DOI: 10.3390/microorganisms9081562.
- Marin, O., B. Gonzalez., & M.J. Poupin. 2021. From microbial dynamics to functionality in the rhizosphere: a systematic review of the opportunities with synthetic microbial communities. *Front Plant Sci.* 12:650609: DOI: 10.3389/FPLS.2021.650609.
- Maryani, N., L. Lombard, Y.S. Poerba, S. Subandiyah., P.W. Crous., & G.H.J. Kema. 2019. Phylogeny and genetic diversity of the banana Fusarium wilt pathogen *Fusarium oxysporum*



UNIVERSITAS  
GADJAH MADA

**Analysis of soil bacteria promoting banana to tolerate fusarium wilt disease (*Fusarium oxysporum* f.sp. *cubense* TR4) in the Special Province of Yogyakarta**  
Irianti Kurniasari, Dr. Ir. Arif Wibowo, M.Agr.Sc; Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc; Anthony B Pattison, Ph.D  
Universitas Gadjah Mada, 2024 | Diunduh dari <http://etd.repository.ugm.ac.id/>

f. sp. *cubense* in the Indonesian centre of origin. *Stud Mycol.* 92: 155-194. DOI: 10.1016/j.simyco.2018.06.003.

Mhete, M., Eze, P.N., Rahube, T.O., & Akinyemi, F.O. 2020. Soil properties influence bacterial abundance and diversity under different land-use regimes in semi-arid environments. *Sci Afr.* 7: e00246. DOI: 10.1016/j.sciaf.2019.e00246.

Moody, P.W., & Chong, P.T. 2008. Soil constraints and management package (SCAMP): guidelines for sustainable management of tropical upland soils. ACIAR Monograph No. 130. Australia.

Moutassem D, Belabid L, Bellik Y, Rouag N, Abed H, Ziouche S, and Baali F. 2019. Role of soil physicochemical and microbiological properties in the occurrence and severity of shickpea's *Fusarium* wilt disease. *Eurasian J of Soil Sci.* 8(4): 304-312. DOI: 10.18393/ejss.585160.

Mousa, W.K., & Raizada, M.N. 2015. Biodiversity of genes encoding antimicrobial traits within plant associated microbes. *Front Plant Sci.* 6: 231. DOI: 10.3389/fpls.2015.00231.

Nam, J.H., Thibodeau, A., Qian, Y.L., Qian, M.C., & Park, S.H. 2023. Multidisciplinary evaluation of plant growth promoting rhizobacteria on soil microbiome and strawberry quality. *AMB Express.* 13 (1): 18. DOI: 10.1186/s13568-023-01524-z.

Nasir, N., Pittaway, P.A., Pegg, K.G., & Lisle, T.A. 1999. A pilot study investigating the complexity of *Fusarium* wilt of banana in West Sumatra, Indonesia. *Aus J Agric Res.* 50: 1279-1283. DOI: 10.1071/AR97079.

Nditasari, A., Agustiyani, D., Noviana, Z., Nugroho, A.A., Purwaningsih, S., Dewi, T.K., Sutisna, E., & Antonius, S. 2023. Microbial community in garlic plants under different applications or organic fertilizer. International Conference of Sains Tanah. Sebelas Maret University, Surakarta, 27-28 July 2022.

Nisrina, L., Effendi, Y., & Pancoro, A. 2021. Revealing the role of plant growth promoting rhizobacteria in suppressive soils against *Fusarium oxysporum* f.sp. *cubense* based on metagenomic analysis. *Heliyon.* 7: e07636. DOI: 10.1016/j.heliyon.2021.e07636.

Obayomi, O., Seyoum, M.M., Ghazaryan, L., Tebbe, C.C., Murase, J., Bernstein, N., & Gillor, O. 2021. Soil texture and properties rather than irrigation water type shape the diversity and composition of soil microbial communities. *Appl Soil Ecol.* 161: 103834. DOI: 10.1016/j.apsoil.2020.103834.

Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., McGlenn, D., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.H., Szöcs, E., & Wagner, H.H. 2019. *Vegan: Community Ecology Package.* R Package Version 2.5-6.

Olivares, B.O., Vega, A., Calderon, M.A.R., Rey, J.C., Lobo, D., Gomez, J.A., & Landa, B.B. 2022. Identification of soil properties associated with the incidence of banana wilt using supervised methods. *Plants.* 11: 2070. DOI: 10.3390/plants11152070.

Orr, R., & Nelson, P.N. 2018. Impacts of soil abiotic attributes on *Fusarium* wilt, focusing on bananas. *Appl Soil Ecol.* 132:20–33. DOI:10.1016/j.apsoil.2018.06.019.



UNIVERSITAS  
GADJAH MADA

**Analysis of soil bacteria promoting banana to tolerate fusarium wilt disease (*Fusarium oxysporum* f.sp. *ubense* TR4) in the Special Province of Yogyakarta**

Irianti Kurniasari, Dr. Ir. Arif Wibowo, M.Agr.Sc; Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc; Anthony B Pattison, Ph.D  
Universitas Gadjah Mada, 2024 | Diunduh dari <http://etd.repository.ugm.ac.id/>

- Oraiz K, Saz VO, Cascante MD, Galvez SM, Garrido ANM, & Asio VB. 2021. Characteristics and nutrient status of limestone soils in Leyte and Samar, Philippines. In: Geo-information Technology for earth Resources Monitoring and Management. (Mishra VN, Rai PK, and Singh P, editors). Nova Science Publishers, New York. Pp: 211-227.
- Osborne, M.G., Simons, A.L., Molano, G., Tolentino, B., Singh, A., Arismendi, G.J.M., Alberto, F., & Nuzhdin, S.V. 2024. Investigating the relationship between microbial network features of giant kelp "seedbank" cultures and subsequent farm performance. PLoS One. 19(3): e0295740. DOI: 10.1371/journal.pone.0295740.
- Peng, H.X., Sivasithamparam, K., & Turner, D.W. 1999. Chlamydospore germination and Fusarium wilt of banana plantlets in suppressive and conducive soils are affected by physical and chemical factors. Soil Biol Biochem. 31: 1363-1374. DOI: 10.1016/S0038-0717(99)00045-0.
- Ploetz, R., S. Freeman., J. Konkol., A. Al-Abed., Z. Naser., K. Shalan, R. Barakat., & Y. Israeli. 2015. Tropical race 4 of Panama disease in the Middle East. Phytoparasitica. 43: 283–293. DOI: 10.1007/s12600-015-0470-5.
- Prigigallo, M.I., Cabanas, C.G., Mercado-Blanco, J., & Bubici, G. 2022. Designing a synthetic microbial community devoted to biological control: the case study of fusarium wilt of banana. Front Microbiol. 13: 967885. DOI: 10.3389/FMICB.2022.967885.
- Promusa. 2021. Tropical race 4. <<https://www.promusa.org/>>. Accessed on 9 September 2021.
- Qia, X., Rufty, T., & Shi, W. 2020. Soil microbial diversity and composition: links to soil texture and associated properties. Soil Biol Biochem. 149: 107953. DOI: 10.1016/j.soilbio.2020.107953.
- Qiao, Y., Wang, Z., Sun, H., Guo, H., Song, Y., Zhang H., Ruan, Y., Xu, Q., Huang Q., Shen, Q., & Ling, N. 2024. Synthetic community derived from grafted watermelon rhizosphere provides protection for ungrafted watermelon against *Fusarium oxysporum* via microbial synergistic effects. Microbiome. 12: 101. DOI: 10.1186/S40168-024-01814-z.
- Rahayu, G., I. Maulana., & Widodo. 2020. Endobacterial symbiont of *Fusarium oxysporum* f.sp. *ubense* and the pathogenicity of their symbiosis towards banana plantling. In: The 3<sup>rd</sup> International conference on Biosciences. IOP Conf. Series: Earth and Environmental Sciences 457. Bogor. 8 August 2020. 1-11.
- R Core Team. 2022. R: A Language and Environment for Statistical Computing.
- Riahi, H.S., Heidarieh, P., & Fatahi-Bafghi, M. 2022. Genus *Pseudonocardia*: What we know about its biological properties, abilities and current application in biotechnology. J Appl Microbiol. 132(2): 890-906. DOI: 10.1111/jam.15271.
- Ridge, J.P., Lin, M., Larsen, E.I., Fegan, M., McEwan, A.G., & Sly, L.I. 2007. A multicopper oxidase is essential for manganese oxidation and laccase-like activity in *Pedomicrobium* sp. ACM 3067. Environ Microbiol. 9(4): 944-953. DOI: 10.1111/j.1462-2920.2006.01216.x.



UNIVERSITAS  
GADJAH MADA

**Analysis of soil bacteria promoting banana to tolerate fusarium wilt disease (*Fusarium oxysporum* f.sp. *cubense* TR4) in the Special Province of Yogyakarta**

Irianti Kurniasari, Dr. Ir. Arif Wibowo, M.Agr.Sc; Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc; Anthony B Pattison, Ph.D  
Universitas Gadjah Mada, 2024 | Diunduh dari <http://etd.repository.ugm.ac.id/>

- Rong, S., Fu-Liang, Q., Yi-Ting, C., Fa-Ping, Z., Wei, D., Ya-Xian, L., Zhi-Pang, H., Xiao-Yan, Y., & Wen, X. 2023. Soil sampling methods for microbial study in montane regions. *Global Ecology and Conservation*. 47: e02679. DOI: 10.1016/j-gecco.2023.e02679.
- Safronova, V.I., Kuznetsova, I.G., Sazanova, A.L., Belimov, A.A., Andronov, E.E., Chirak, E.R., Osledkin, Y.S., Onishchuk, O.P., Kurchak, O.N., Shaposhnikov, A.I., Willems, A., & Tikhonovich, I.A. 2017. *Microvirga ossetica* sp. nov., a species of rhizobia isolated from root nodules of the legume species *Vicia alpestris* Steven. *Intl J Syst Evol Microbiol*. 67(1): 94-100. DOI: 10.1099/ijsem.0.001577.
- Segata, N., Izard, J., Waldron, L., Gevers, D., Miropolsky, L., Garrett, W.S., & Huttenhower, C. 2011. Metagenomic biomarker discovery and explanation. *Genom Biol*. 12(6): R20. DOI: 10.1186/gb-2011-12-6-r60.
- Sekhar, A.C., & Thomas, P. 2015. Isolation and identification of shoot-tip associated endophytic bacteria from banana cv. Grand Naine and testing for antagonistic activity against *Fusarium oxysporum* f. sp. *cubense*. *Am. J Plant Sci*. 6(7): 943–954. DOI: 10.4236/ajps.2015.67101.
- Shayanthan, A., Ordonez, P.A.C., & Oresnik, J. 2022. The role of synthetic microbial communities (SynCom) in sustainable agriculture. *Front Agron*. 4(896307): 1-13. DOI: 10.3389/fagro.2022.896307.
- Shannon, P., Markiel, A., Ozier, O., Baliga, N.S., Wang, J.T., Ramage, D., Amin, N., Schwikowski, B., & Ideker, T. 2003. Cytoscape: A software environment for integrated models of biomolecular interaction networks. *Genome Res*. 13(11): 2498-2504. DOI: 10.1101/gr.1239303.
- Shen, F-T., & Lin, S-H. 2021. Shifts in bacterial community associated with green manure soybean intercropping and edaphic properties in a tea plantation. *Sustainability*. 13(20): 11478. DOI: 10.3390/su132011478.
- Shivlata, L., & Satyanarayana, T. 2015. Thermophilic and alkaliphilic *Actinobacteria*: Biology and potential applications. *Front Microbiol*. 6: 1014. DOI: 10.3389/fmicb.2015.01014.
- Simko, I., & Piepho, H. 2012. The area under the disease progress stairs: calculation, advantage, and application. *Anal Theo Plant Pathol*. 102(4): 381-389. DOI: 10.1094/PHYTO-07-11-0216.
- Soni, R., Kumar, V., Suyal, D.C., Jain, L., & Goel, R. 2017. Metagenomics of plant rhizosphere microbiome. In: Singh, R.P (Eds.). *Understanding Host-Microbiome Interactions-An Omics Approach*. Springer Nature Singapore. Pte Ltd. 193-205.
- Świątczak, J., Kalwasińska, A., Szabó, A., & Brzezinska, M.S. 2023. *Pseudomonas sivasensis* <sub>2</sub>RO<sub>45</sub> inoculation alters the taxonomic structure and functioning of the canola rhizosphere microbial community. *Front Microbiol*. 14: 1168907. DOI: 10.3389/fmicb.2023.1168907.
- Tan, S.Y., Yang, C.L., Mei, X.L., Shen, S.Y., Raza, W., Shen, Q.R., & Yu, X.C. 2013. The effect of organic acids from tomato root exudates on rhizosphere colonization of *Bacillus amyloliquefaciens* T-5. *Appl Soil Ecol*. 64: 15-22. DOI: 10.1016/j.apsoil.2012.10.011.



UNIVERSITAS  
GADJAH MADA

**Analysis of soil bacteria promoting banana to tolerate fusarium wilt disease (*Fusarium oxysporum* f.sp. *ubense* TR4) in the Special Province of Yogyakarta**  
Irianti Kurniasari, Dr. Ir. Arif Wibowo, M.Agr.Sc; Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc; Anthony B Pattison, Ph.D  
Universitas Gadjah Mada, 2024 | Diunduh dari <http://etd.repository.ugm.ac.id/>

- Tang, L., Xia, Y., Fan, C., Kou, J., Wu, F., Li, W., & Pan, K. 2020. Control of Fusarium wilt by wheat straw is associated with microbial network changes in watermelon rhizosphere. *Sci Rep.* 10: 12736. DOI: 10.1038/S41598-020-69623-6.
- Thomas, T., Gilbert, J., & Meyer, F. 2012. Metagenomics a guide from sampling to data analysis. *Microb Inform Exp.* 2:3. DOI: 10.1186/2042-5783-2-3.
- Tibuhwa, D.D., & Shomari, S. 2016. Fusarium wilt disease: an emerging threat to cashew nut crop production in Tanzania. *Asian J Plant Pathol.* 10: 36-48. DOI: 10.3923/ajppaj.2016.36.48.
- Turner, T.R., James, E.K., & Poole, P.S. 2013. The plant microbiome. *Genome Biol.* 14: 209. DOI: 10.1186/gb-2013-14-6-209.
- Ulilalbab, A.R., Widinugraheni, S., Masanto, Subandiyah, S., & Wibowo, A. 2022. Expression of *SIX1b* and *SIX1c* effector genes and banana resistance genes during *Foc* TR4 infection on banana cultivars. *Biodiversitas.* 23 (10): 5314-5322. DOI: 10.13057/biodiv/d231041.
- Umar, H.B. 2009. Principal component analysis (PCA) dan aplikasinya dengan SPSS. *J Kes Mas.* 3(2): 97-101.
- Watts, S.C., Ritchie, S.C., Inouye, M., & Holt, K.E. 2018. FastSpar: Rapid and scalable correlation estimation for compositional data. *Bioinformatics.* 35(6): 1064-1066. DOI: 10.1093/bioinformatics/bty734.
- Weinert M and Simpson M. 2016. Sub tropical banana nutrition-matching nutrition requirements to growth demands. 28p
- Wibowo, A., Suryanti, & Sumardiyono, C. 2001. Patogenisitas 6 Isolat *Fusarium oxysporum* f. sp. *ubense* penyebab penyakit layu *Fusarium* pada pisang. In: Kongres XVI dan Seminar Nasional PFI. Bogor, 22-24 August 2001. [Indonesian]
- Wibowo, A., Subandiyah, S., Sumardiyono, S., Sulistyowati, L., Taylor, P., & Fegan, M. 2011. Occurrence of tropical race 4 of *Fusarium oxysporum* f.sp. *ubense* in Indonesia. *Plant Pathol J.* 27(3): 280-284. doi.10.5423/PPJ.2011.27.3.280.
- Wickham, H. 2016. Ggplot2: Elegant Graphics for Data Analysis. Springer- Verlag, New York.
- Wood, D.E., Lu, J., & Langmead, B. 2019. Improved metagenomic analysis with Kraken 2. *Genome Biol.* 20(1): 257. DOI: 10.1186/s13059-019-1891-0.
- Xue, C., Penton, C.R., Shen, Z., Zhang, R., Huang, Q., Li, R., Ruan, Y., & Shen, Q. 2015. Manipulating the banana rhizosphere microbiome for biological control of Panama disease. *Sci. Rep.* 5: 11124. DOI: 10. 1038/srep11124.
- Xiao, Y., Zhang, S., Li, H., Teng, K., Wu, S., Liu, Y., Yu, F., He, Z., Li, L., Li, L., Meng, D., Yin, H., & Wang, Y. 2024. Metagenomic insights into the response of soil microbial communities to pathogenic *Ralstonia solanacearum*. *Front Plant Sci.* 15: 1325141. DOI: 10.3389/fpls.2024.1325141.



UNIVERSITAS  
GADJAH MADA

**Analysis of soil bacteria promoting banana to tolerate fusarium wilt disease (*Fusarium oxysporum* f.sp. *cubense* TR4) in the Special Province of Yogyakarta**

Irianti Kurniasari, Dr. Ir. Arif Wibowo, M.Agr.Sc; Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc; Anthony B Pattison, Ph.D

Universitas Gadjah Mada, 2024 | Diunduh dari <http://etd.repository.ugm.ac.id/>

- Yang, F., Jiang, H., Chang, G., Liang, S., Ma, K., Cai, Y., Tian, B., & Shi, X. 2023. Effects of rhizosphere microbial communities on cucumber *Fusarium* wilt disease suppression. *Microorganisms*. 11(6): 1576. DOI: 10.3390/microorganisms11061576.
- Yetgin, A. 2023. Exploring the link between soil microbial diversity and nutritional deficiencies. *J Prod Agric*. 4(2): 81-90. DOI: 10.56430./japro.1279830.
- Yuan, J., Zhang, N., Huang, Q., Raza, W., Li, R., Vivanco, J.M., & Shen, Q. 2015. Organic acids from root exudates of banana help root colonization of PGPR strain *Bacillus amyloliquefaciens* NJN-6. *Sci Rep*. 5: 13438. DOI: 10.1038/srep13438.
- Zeng, T., Wang, L., Zhang, X., Song, X., Li, J., Yang, J., Chen, S., & Zhang, J. 2022. Characterization of microbial communities in wastewater treatment plants containing heavy metals located in chemical industrial zones. *Intl J Environ Res Public Health*. 19 (11): 6529. DOI: 10.3390/ijerph19116529.
- Zhang, T., Chen, H.Y.H., & Ruan, H. 2018. Global negative effects of nitrogen deposition on soil microbes. *ISME J*. 12: 1817-1825. DOI: 10.1038/s41396-018-0096-y.