UNIVERSITAS
GADJAH MADA

Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

DAFTAR PUSTAKA

Aalipour, H., Nikbakht, A., & Etemadi, N. (2019). Relationship between chlorosis, photo- synthesis and the nutrient content of plane trees in the presence of chemical and organic fertilizers. *Adv. Hort. Sci.*, *33*(January), 171–177. https://doi.org/10.13128/ahs-23326

Abdullah, F. (1996). Basidiomata Induction and Characterization of Ganoderrna from Oil Palm (Elaeis guineensis) on Three Agrowaste Substrates. *Pertanika J. Trap. Agric. Sci. 19(2/3):*, *19*(2), 117–122.

Abhayashree, M. S., Murali, M., & Amruthesh, K. N. (2016). Scientia Horticulturae Abiotic elicitors mediated resistance and enhanced defense related enzymes in Capsicum annuum L . against anthracnose disease. *Scientia Horticulturae*, *204*, 172–178. https://doi.org/10.1016/j.scienta.2016.04.004

Adotey, G., Quarcoo, A., Gedel, M. A., Yerenkyi, P., Otu, P., Anang, A. K., Okine, L. K. N., Gbewonyo, W. S. K., Holliday, J. C., & Lombardi, V. C. (2026). The Medicinal Mushroom Ganoderma: A Review of Systematics, Phylogeny, and Metabolomic Insights. *Journal of Fungi*, *12*(1), 1–17. https://doi.org/10.3390/jof12010058

Afandi, D., Basyni, M., Putri, L. A. P., Chalil, D., & Syahputra, I. (2018). Expression of oil palm (Elaeis guineensis) polyisoprenoids in response to Ganoderma boninense infection. *Biodiversitas Journal of Biological Diversity*, *20*(1), 68–76. https://doi.org/10.13057/biodiv/d200109

Alexander, A., Dayou, J., Abdullah, S., & Phin, C. K. (2019). Differential expression and profile of oil palm root-sterols composition related to Ganoderma boninense infection. *ASM Science Journal*, *12*(Special Issue 3), 40–47.

Annunziata, M. G., Ciarmiello, L. F., Woodrow, P., Aversana, E. D., & Carillo, P. (2019). Spatial and Temporal Profile of Glycine Betaine Accumulation in Plants Under Abiotic Stresses. *Frontiers in Plant Science*, *10*(March), 1–13. https://doi.org/10.3389/fpls.2019.00230

Anothai, J., & Chairin, T. (2020). Soil physicochemical properties closely associated with fungal enzymes and plant defense enzymes in Ganoderma -infected oil palm orchards. *Plant Soil*, *456*, 99–112. https://doi.org/https://doi.org/10.1007/s11104-020-04705-y

Anothai, J., Intara, S., & Thanunchanok, S. (2023). Understanding factors influencing growth and lignocellulosic enzyme of Ganoderma for developing integrated control strategies for basal stem rot disease in oil palm. *Tropical Plant Pathology*, *48*(2), 154–162. https://doi.org/10.1007/s40858-022-00551-8

Asis, J., Hasbullah, N. A., Jalloh, M. B., Basri, N. K. M., Perumal, P., Mojiun, P., & Rakib, M. R. M. (2024). Trichoderma Species' In Vitro and In Planta Inhibition against Ganoderma boninense, a Causative Agent of Basal Stem Rot in Oil Palm (Elaeis guineensis). *Sarhad Journal of Agriculture*, *40*(SpecialIssue1), 173–185. https://doi.org/10.17582/JOURNAL.SJA/2024/40/S1.173.185

Bahari, M. N. A., Sakeh, N. M., Abdullah, S. N. A., Ramli, R. R., & Kadkhodaei, S. (2018). Transciptome profiling at early infection of Elaeis guineensis by

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Ganoderma boninense provides novel insights on fungal transition from biotrophic to necrotrophic phase. *BMC Plant Biology*, *18*(1), 1–25. https://doi.org/10.1186/s12870-018-1594-9

Baharum, S. N., Ahmad, M. F., Ajeng, A. A., & Abdullah, R. (2023). Metabolites profiling of Ganoderma-infected oil palms rachis grown on tropical soils reveals choline phosphate and 2-oxoglutaramate as potential biomarkers in the disease detection. *Physiological and Molecular Plant Pathology*, *125*, 102001. https://doi.org/10.1016/j.pmpp.2023.102001

Bakhshi, M., Ebrahimi, L., Zare, R., Arzanlou, M., & Kermanian, M. (2022). Development of a Novel Diagnostic Tool for Cercospora Species Based on BOX-PCR System. *Current Microbiology*, *79*(10), 1–8. https://doi.org/10.1007/s00284-022-02989-0

Basit, F., Alyafei, M., Hayat, F., Al-zayadneh, W., El-keblawy, A., Sulieman, S., & Sheteiwy, M. S. (2025). *Deciphering the role of glycine betaine in enhancing plant performance and defense mechanisms against environmental stresses*. *16*(July), 1582332. https://doi.org/10.3389/fpls.2025.1582332

Bharudin, I., Ab Wahab, A. F. F., Abd Samad, M. A., Xin Yie, N., Zairun, M. A., Abu Bakar, F. D., & Abdul Murad, A. M. (2022). Review Update on the Life Cycle, Plant–Microbe Interaction, Genomics, Detection and Control Strategies of the Oil Palm Pathogen Ganoderma boninense. *Biology*, *11*(2), 1–18. https://doi.org/10.3390/biology11020251

Bivi, M. S. H. R., Paiko, A. S., Khairulmazmi, A., Akhtar, M. S., & Idris, A. S. (2016). Control of Basal Stem Rot Disease in Oil Palm by Supplementation of Calcium , Copper , and Salicylic Acid. *The Plant Pathology Journal*, *32*(5), 396–406. https://doi.org/http://dx.doi.org/10.5423/PPJ.OA.03.2016.0052

Boddy, L. (2016). Genetics-Variation, Sexuality, and Evolution. In *The Fungi: Third Edition* (Third Edit). Elsevier Ltd. https://doi.org/10.1016/B978-0-12-382034-1.00004-9

Bolton, M. (2009). Primary Metabolism and Plant Defense—Fuel for the Fire. *Molecular Plant-Microbe Interactions*, *22*(5), 487–497. papers://6aa7c312-319c-4536-9f53-abd54d6cbe0f/Paper/p632

Botahala, L., Sukarti, Arifuddin, W., Arif, A. R., Ischaidar, Arafah, M., Kartina, D., Armah, Z., Yasser, M., Pratama, I., Patarru, O., Santi, & Hamsah, H. (2020). *Deteksi Dini Metabolit Sekunder pada Tanaman*. Mitra Cendekia Media. http://repo.untribkalabahi.ac.id/xmlui/handle/123456789/315

BPDPKS. (2021). *Laporan Tahunan: Pengembangan Sumber Daya Manusia Perkebunan Kelapa Sawit sebagai Upaya Menuju Sawit Indonesia yang Berkelanjutan*.

Bruger, E. L., Hying, Z. T., Singla, D., Reyes, N. L. M., Pandey, S. K., Patel, J. S., & Bazurto, J. V. (2024). Enhanced catabolism of glycine betaine and derivatives provides improved osmotic stress protection in Methylorubrum extorquens PA1. *Applied and Environmental Microbiology*, *90*(7), 1–26. https://doi.org/https://doi.org/ 10.1128/aem.02090-23

Cabarroi-hernández, M., Villalobos-arámbula, A. R., Torres-Torres, M. G., Decock, C., & Guzmán-Dávalos, L. (2019). The Ganoderma weberianum-resinaceum lineage: multilocus phylogenetic analysis and morphology confirm G.

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

mexicanum and G. parvulum in the Neotropics. *MycoKeys*, *59*, 95–131. https://doi.org/10.3897/mycokeys.59.33182

Camacho, C., Coulouris, G., Avagyan, V., Ma, N., Papadopoulos, J., Bealer, K., & Madden, T. L. (2009). BLAST+: Architecture and applications. *BMC Bioinformatics*, *10*, 1–9. https://doi.org/10.1186/1471-2105-10-421

Campos-Bermudez, V. A., Fauguel, C. M., Tronconi, M. A., Casati, P., Presello, D. A., & Andreo, C. S. (2013). Transcriptional and Metabolic Changes Associated to the Infection by Fusarium verticillioides in Maize Inbreds with Contrasting Ear Rot Resistance. *PLoS ONE*, *8*(4). https://doi.org/10.1371/journal.pone.0061580

Castillo, S. Y., Rodríguez, M. C., González, L. F., Zúñiga, L. F., Mestizo, Y. A., Medina, H. C., Montoya, C., Morales, A., Romero, H. M., & Sarria, G. A. (2022). Ganoderma zonatum Is the Causal Agent of Basal Stem Rot in Oil Palm in Colombia. *Journal of Fungi*, *8*, 230. https://doi.org/10.3390/jof8030230

Castro-moretti, F. R., Gentzel, I. N., Mackey, D., & Alonso, A. P. (2020). Metabolomics as an emerging tool for the study of plant–pathogen interactions. *Metabolites*, *10*(2), 1–23. https://doi.org/10.3390/metabo10020052

Cavalcanti, F. R., Resende, M. L. V., Lima, J. P. M. S., Silveira, J. A. G., & Oliveira, J. T. A. (2006). Activities of antioxidant enzymes and photosynthetic responses in tomato pre-treated by plant activators and inoculated by Xanthomonas vesicatoria. *Physiological and Molecular Plant Pathology*, *68*(4–6), 198–208. https://doi.org/10.1016/j.pmpp.2006.11.001

Chan, Y. S., & Chong, K. P. (2019). Novel media for cultivation of fruiting body of Ganoderma boninense for medicinal benefits. *ASM Science Journal*, *12*(Special Issue 3), 11–16.

Chen, J., Zhang, J., Liu, Y., Zhang, K., Zhu, F., & Xie, Y. (2025). Advances in the Biosynthetic Regulation and Functional Mechanisms of Glycine Betaine for Enhancing Plant Stress Resilience. *International Journal of Molecular Sciences*, *26*(16), 1–23. https://doi.org/10.3390/ijms26167971

Choi, Y. W., Hodgkiss, I. J., & Hyde, K. D. (2005). Enzyme production by endophytes of Brucea javanica. *Journal of Agricultural Technology*, *1*, 55–66.

Chong, K.-P., Alexander, A., & Abdullah, S. (2016). Early Detection and Management of Ganoderma Basal Stem Rot Disease: A Special Report from Sabah. *Transactions on Science and Technology*, *3*(3), 16–17. http://transectscience.org/

Chong, K. P. (2012). The potential of chitosan in suppressing Ganoderma boninense infection in oil-palm seedlings. *Journal of Sustainability Science and Management*, *7*(2), 186–192.

Chong, K. P., Dayou, J., & Alexander, A. (2017). Pathogenic Nature of Ganoderma boninense and Basal Stem Rot Disease. In *Detection and Control of Ganoderma boninense in Oil Palm Crop* (pp. 5–12). SpringerBriefs in Agriculture. Springer, Cham. https://doi.org/10.1007/978-3-319-54969-9_2

Chong, K. P., Lum, M. S., Foong, C. P., Wong, C. M. V. L., Atong, M., & Rossall, S. (2011). First identification of ganoderma boninense isolated from sabah based on PCR and sequence homology. *African Journal of Biotechnology*, *10*(66), 14718–14723. https://doi.org/10.5897/AJB11.1096

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Chung, G. F. (2012). Effect of Pests and Diseases on Oil Palm Yield. In *Palm Oil: Production, Processing, Characterization, and Uses*. AOCS Press. https://doi.org/10.1016/B978-0-9818936-9-3.50009-5

Cornara, L., Mandrone, M., & Smeriglio, A. (2024). Biotic and Abiotic Stressors in Plant Metabolism. *International Journal of Molecular Sciences*, *25*, 121. https://doi.org/https:// doi.org/10.3390/ijms25010121

Cortina-Escribano, M., Veteli, P., Wingfield, M. J., Wingfield, B. D., Coetzee, M. P. A., Vanhanen, H., & Linnakoski, R. (2024). Phylogenetic analysis and morphological characteristics of laccate Ganoderma specimens in Finland. *Mycologia*, *116*(6), 1046–1062. https://doi.org/10.1080/00275514.2024.2381424

Daim, L. D. J., Ooi, T. E. K., Ithnin, N., Mohd Yusof, H., Kulaveerasingam, H., Majid, N. A., & Karsani, S. A. (2015). Comparative proteomic analysis of oil palm leaves infected with Ganoderma boninense revealed changes in proteins involved in photosynthesis, carbohydrate metabolism, and immunity and defense. *Electrophoresis*, *36*(15), 1699–1710. https://doi.org/10.1002/elps.201400608.This

David, L., Kang, J., Dufresne, D., Zhu, D., & Chen, S. (2021). Multi-omics revealed molecular mechanisms underlying guard cell systemic acquired resistance. *International Journal of Molecular Sciences*, *22*(1), 1–22. https://doi.org/10.3390/ijms22010191

Dutton, C., Hõrak, H., Hepworth, C., Mitchell, A., Ton, J., Hunt, L., & Gray, J. E. (2019). Bacterial infection systemically suppresses stomatal density. *Plant Cell and Environment*, *42*(8), 2411–2421. https://doi.org/10.1111/pce.13570

Dzulkafli, S. B., Othman, A., Shahwan, S., Nurazah, Z., Abd Manaf, M. A., Idris, A. S., Amiruddin, M. D., Tahir, N. I., & Ramli, U. S. (2019). Identification of chelidonic acid and asparagine in Ganoderma boninense - inoculated oil palm seedlings. *Journal of Oil Palm Research*, *31*(1), 53–66.

Elisashvili, V., Kachlishvili, E., Tsiklauri, N., Metreveli, E., Khardziani, T., & Agathos, S. N. (2009). Lignocellulose-degrading enzyme production by white-rot Basidiomycetes isolated from the forests of Georgia. *World Journal of Microbiology and Biotechnology*, *25*(2), 331–339. https://doi.org/10.1007/s11274-008-9897-x

Faizah, R., Putranto, R. A., Raharti, V. R., Supena, N., Sukma, D., Budiani, A., Wening, S., & Sudarsono, S. (2022). Defense response changes in roots of oil palm (Elaeis guineensis Jacq.) seedlings after internal symptoms of Ganoderma boninense Pat. infection. *BMC Plant Biology*, *22*(1), 1–23. https://doi.org/10.1186/s12870-022-03493-0

Fernanda, R., Siddiqui, Y., Ganapathy, D., Ahmad, K., & Surendran, A. (2021). Suppression of ganoderma boninense using benzoic acid: Impact on cellular ultrastructure and anatomical changes in oil palm wood. *Forests*, *12*, 1231. https://doi.org/10.3390/f12091231

Flood, J., Cooper, R., Rees, R., Potter, U., & Hasan, Y. (2014). Some Latest R & D on Ganoderma Diseases in Oil Palm. *OPRI/MPOB Seminar: Advances in the Controlling of Devastating Disease of Oil Palm (Ganoderma) in South East Asia*, 1–21.

Goh, Y. K., Ng, F. W., Kok, S. M., Goh, Y. K., & Goh, K. J. (2014). Aggressiveness of

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Ganoderma boninense isolates on the vegetative growth of oil palm (Elaeis guineensis) seedlings at different ages. *Malaysian Applied Biology*, *43*(2), 9–16.

Gomes, A., Santos, C., Dinis, L. T., & Mendes, R. J. (2024). Escherichia coli Inoculation Decreases the Photosynthetic Performance on Tomato Plants: Clarifying the Impact of Human Commensal Bacteria on Transient Plant Hosts. *Horticulturae*, *10*(7), 1–12. https://doi.org/10.3390/horticulturae10070758

Govender, N., Mahmood, M., Seman, I. A., & Wong, M. Y. (2017). The phenylpropanoid pathway and lignin in defense against Ganoderma boninense colonized root tissues in oil palm (Elaeis guineensis jacq.). *Frontiers in Plant Science*, *8*(August), 1–11. https://doi.org/10.3389/fpls.2017.01395

Govender, N., Mui-Yun, W., & Paterson, R. R. M. (2020). Opportunities for New-Generation Ganoderma boninense Biotechnology. In *Grand Challenges in Biology and Biotechnology* (Number September, pp. 477–500). https://doi.org/10.1007/978-3-030-29541-7_17

Govender, N., & Wong, M. Y. (2017). Detection of oil palm root penetration by agrobacterium-mediated transformed ganoderma boninense, expressing green fluorescent protein. *Phytopathology*, *107*(4), 483–490. https://doi.org/10.1094/PHYTO-02-16-0062-R

Habermann, G., Machado, E. C., Rodrigues, J. D., & Medina, C. L. (2003). Gas exchange rates at different vapor pressure deficits and water relations of “Pera” sweet orange plants with citrus variegated chlorosis (CVC). *Scientia Horticulturae*, *98*(3), 233–245. https://doi.org/10.1016/S0304-4238(02)00228-5

Hahuly, M. V., Sumardiyono, C., Wibowo, A., Subandiyah, S., & Harper, S. (2018). Identification of purple blotch pathogen of shallot by PCR using specific primer for Alternaria genus. *Archives of Phytopathology and Plant Protection*, *51*(3–4), 103–121. https://doi.org/10.1080/03235408.2017.1384196

Hamid, S., Nor, S., & Abdullah, A. (2025). The elicitation of early defence responses and improvement of disease resistance in oil palm by extracellular proteins from Ganoderma boninense. *European Journal of Plant Pathology*, 143–163. https://doi.org/10.1007/s10658-025-03052-x

Han, X., Li, X., White, J. F., Creamer, R., Li, C., & Yu, B. (2024). Alterations in Physiological Parameters and Secondary Metabolites of Astragalus adsurgens Infected by the Pathogen Alternaria gansuensis. *Agronomy*, *14*, 1892. https://doi.org/10.3390/agronomy14091892

Han, Y.-L., Wang, D., Zhou, J., He, X.-L., & Cui, B.-K. (2019). Intragenomic polymorphisms of the ITS, EF1-α and RPB2 sequences of Ganoderma australe. *Mycosystema*, *38*(5), 679–685. https://doi.org/10.13346/j.mycosystema.180293

Hapuarachchi, K., Karunarathna, S., Phengsintham, P., Yang, H., Kakumyan, P., Hyde, K., & Wen, T. (2019). Ganodermataceae (Polyporales): Diversity in Greater Mekong Subregion countries (China, Laos, Myanmar, Thailand and Vietnam). *Mycosphere*, *10*(1), 221–309. https://doi.org/10.5943/mycosphere/10/1/6

Hermantoro, Kurniawan, M. A., Trinugroho, J. P., Suparyanto, T., Isnan, M., Sudigyo, D., & Pardamean, B. (2023). Detecting Ganoderma Basal Stem Rot Disease On Oil Palm Using Artificial Neural Network Method. *Commun. Math. Biol. Neurosci*, *40*, 1–16. https://doi.org/https://doi.org/10.28919/cmbn/7911

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Hilmi, N. H. Z., Idris, A. S., Maizatul-Suriza, M., Madihah, A. Z., & Nur-Rashyeda, R. (2022). Molecular PCR assays for detection of Ganoderma pathogenic to oil palm in Malaysia. *Malaysian Applied Biology*, *51*(1), 171–182. https://doi.org/10.55230/MABJOURNAL.V51I1.2201

Hu, Z., Chang, X., Dai, T., Li, L., Liu, P., Wang, G., Liu, P., Huang, Z., & Liu, X. (2019). Metabolic Profiling to Identify the Latent Infection of Strawberry by Botrytis cinerea. *Evolutionary Bioinformatics*, *15*, 1–7. https://doi.org/10.1177/1176934319838518

Idle, J. R., & Gonzalez, F. J. (2007). Metabolomics. *Cell Metabolism*, *6*(5), 348–351. https://doi.org/10.1016/j.cmet.2007.10.005

Isha, A., Akanbi, F. S., Yusof, N. A., Osman, R., Mui-Yun, W., & Abdullah, S. N. A. (2019). An NMR metabolomics approach and detection of ganoderma boninense-infected oil palm leaves using MWCNT-based electrochemical sensor. *Journal of Nanomaterials*, *2019*, 4729706. https://doi.org/10.1155/2019/4729706

Isha, A., Yusof, N. A., Osman, R., Wong, M. Y., & Abdullah, S. N. A. (2020). NMR-based metabolomics reveals effect of Ganoderma boninense infection on oil palm leaf at 30 days post-infection. *Plant Omics Journal*, *13*(1), 15–20. https://doi.org/10.21475/POJ.13.01.20.P2071

Isha, A., Yusof, N. A., Shaari, K., Osman, R., Abdullah, S. N. A., & Wong, M. Y. (2020). Metabolites identification of oil palm roots infected with Ganoderma boninense using GC–MS-based metabolomics. *Arabian Journal of Chemistry*, *13*(7), 6191–6200. https://doi.org/10.1016/j.arabjc.2020.05.026

Jargalmaa, S., Eimes, J. A., Park, M. S., Park, J. Y., Oh, S., & Lim, Y. W. (2017). Taxonomic evaluation of selected Ganoderma species and database sequence validation. *PeerJ*, *5*, e3596. https://doi.org/10.7717/peerj.3596

Jarin, A., Ghosh, U. K., Hossain, M. S., Mahmud, A., & Khan, M. A. R. (2024). Glycine betaine in plant responses and tolerance to abiotic stresses. *Discover Agriculture*, *2*(1), 127. https://doi.org/10.1007/s44279-024-00152-w

Jazuli, N. A., Kamu, A., Chong, K. P., Gabda, D., Hassan, A., Abu Seman, I., & Ho, C. M. (2022). A Review of Factors Affecting Ganoderma Basal Stem Rot Disease Progress in Oil Palm. *Plants*, *11*, 2462. https://doi.org/10.3390/plants11192462

Jeger, M. J., & Viljanen-rollinson, S. L. H. (2001). The use of the area under the disease-progress curve (AUDPC) to assess quantitative disease resistance in crop cultivars. *Theoretical and Applied Genetics*, *102*, 32–40. https://doi.org/https://doi.org/10.1007/s001220051615

Jiang, X., Walker, B. J., He, S. Y., & Hu, J. (2023). The role of photorespiration in plant immunity. *Frontiers in Plant Science*, *14*(February), 1–8. https://doi.org/10.3389/fpls.2023.1125945

Kaur, R., Chandra, J., Varghese, B., & Keshavkant, S. (2023). Allantoin : A Potential Compound for the Mitigation of Adverse Effects of Abiotic Stresses in Plants. *Plants*, *12*, 3059. https://doi.org/https://doi.org/10.3390/plants12173059

Khairi, M. H. F., Nor Muhammad, N. A., Bunawan, H., Mohd Daud, K., Sulaiman, S., Mohamed-hussein, Z., Wong, M., & Ramzi, A. B. (2024). Current progress on the computational methods for prediction of host-pathogen protein-protein

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

interaction in the Ganoderma boninense -oil palm pathosystem. *Physiological and Molecular Plant Pathology*, *129*(July 2023), 102201. https://doi.org/10.1016/j.pmpp.2023.102201

Khoo, Y. W., & Chong, K. P. (2023). Ganoderma boninense : general characteristics of pathogenicity and methods of control. *Front. Plant Sci.*, *14*, 1156869. https://doi.org/10.3389/fpls.2023.1156869

Kim, H. K., Choi, Y. H., & Verpoorte, R. (2010). NMR-based metabolomic analysis of plants. *Nature Protocols*, *5*(3), 536–549. https://doi.org/10.1038/nprot.2009.237

Kok, S., Goh, Y., Tung, H., GoH, K., Wong, W., & Goh, Y. (2013). In vitro growth of Ganoderma boninense isolates on novel palm extract medium and virulence on oil palm (Elaeis guineensis) seedlings. *Malaysian Journal of Microbiology*, *9*(1), 33–42. https://doi.org/10.21161/mjm.45212

Kresnawaty, I., Audah, K. A., Munawar, H., & Widiastuti, H. (2017). Karakteristik antibodi anti Ganoderma sp. yang dihasilkan dengan menggunakan jenis dan sumber antigen yang berbeda. *Menara Perkebunan*, *85*(1), 1–8. https://doi.org/http://dx.doi.org/10.22302/iribb.jur.mp.v85i1.239

Kresnawaty, I., Mulyatni, A. S., Eris, D. D., Prakoso, H. T., Tri-Panji, Triyana, K., & Widiastuti, H. (2020). Electronic nose for early detection of basal stem rot caused by Ganoderma in oil palm. *IOP Conference Series: Earth and Environmental Science*, *468*, 012029. https://doi.org/10.1088/1755-1315/468/1/012029

Lakshmi, M. A., Bishnoi, S., Ho, C., Tarafder, E., Babu, B. K., Subbanna, A., Sahu, S., & Palnam, D. W. (2025). First pathogenomic insights into Ganoderma ellipsoideum as an emerging causal agent of basal stem rot in oil palm. *Scientific Reports* |, *15*(45743), 1–14. https://doi.org/https://doi.org/10.1038/s41598-025-28488-3 1

Lakshmi, M. A., Indraja, M., Palnam, D. W., Tarafder, E., Cs, K., Babu, B. K., & Subanna, A. (2026). First Report of Ganoderma ellipsoideum Causing Basal Stem Rot in. *Plant Disease*, *110*, 539. https://doi.org/https://doi.org/10.1094/PDIS-06-25-1162-PDN

Latiffah, Z., & Ho, Y. W. (2005). Morphological Characteristics and Somatic Incompatibility of Ganoderma from Infected Oil Palm from Three Inland Estates. *Malaysian Journal of Microbiology*, *1*(2), 46–52.

Liaubet, L., Paris, A., Tardivel, P., Pe, M., Iannuccelli, N., Vialaneix, N., & Toulouse, D. (2019). ASICS : an R package for a whole analysis workflow of 1D 1H NMR spectra. *Bioinformatics*, *35*(21), 4356–4363. https://doi.org/10.1093/bioinformatics/btz248

Lieng, L. M. (2024). *Characterisation of Ganoderma boninense Isolates from Sarawak, the Causal Agent of Basal Stem Rot in Elaeis guineensis*. Universiti Malaysia Sarawak.

Liu, S., Gates, G., & Gibertoni, T. B. (2022). Species diversity, systematic revision and molecular phylogeny of Ganodermataceae (Polyporales, Basidiomycota) with an emphasis on Chinese collections. *Studies in Mycology*, *101*, 287–415. https://doi.org/10.3114/sim.2022.101.05.Received

Lo, M. L., Thanh, T. A. V., Midot, F., Lau, S. Y. L., Wong, W. C., Tung, H. J., Jee, M. S., Chin, M. Y., & Melling, L. (2023). Comparison of Ganoderma boninense

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Isolate's Aggressiveness Using Infected Oil Palm Seedlings. *Journal of Microbiology*, *61*(4), 449–459. https://doi.org/10.1007/s12275-023-00040-w

Maharachchikumbura, S. S. N., Chen, Y., Ariyawansa, H. A., Hyde, K. D., Haelewaters, D., Perera, R. H., Samarakoon, M. C., Wanasinghe, D. N., Bustamante, D. E., Liu, J. K., Lawrence, D. P., Cheewangkoon, R., & Stadler, M. (2021). Integrative approaches for species delimitation in Ascomycota. *Fungal Diversity*, *109*(1), 155–179. https://doi.org/10.1007/s13225-021-00486-6

Maillot, Y., Mongelard, G., Quero, A., Demailly, H., Guenin, S., Gutierrez, L., Pineau, C., Lecomte, S., Mathiron, D., Elboutachfaiti, R., Fontaine, J., Molinie, R., & Petit, E. (2023). Pathogen Stopping and Metabolism Modulation Are Key Points to Linum usitatissimum L. Early Response against Fusarium oxysporum. *Plants*, *12*, 1963. https://doi.org/https://doi.org/ 10.3390/plants12101963

Manickam, S., Rajagopalan, V. R., Kambale, R., Rajasekaran, R., Kanagarajan, S., & Muthurajan, R. (2023). Plant Metabolomics: Current Initiatives and Future Prospects. *Current Issues in Molecular Biology*, *45*(11), 8894–8906. https://doi.org/10.3390/cimb45110558

Manzanilla-López, R. H., Clark, I. M., Atkins, S. D., Hirsch, P. R., & Kerry, B. R. (2009). Rapid and reliable DNA extraction and PCR fingerprinting methods to discriminate multiple biotypes of the nematophagous fungus Pochonia chlamydosporia isolated from plant rhizospheres. *Letters in Applied Microbiology*, *48*(1), 71–76. https://doi.org/10.1111/j.1472-765X.2008.02489.x

Matous, K., Bonfig, K., Mueller, M. J., Berger, S., & Benediktyova, Z. (2007). Visualization of dynamics of plant – pathogen interaction by novel combination of chlorophyll fluorescence imaging and statistical analysis : differential effects of virulent and avirulent strains of P . syringae and of oxylipins on. *Journal of Experimental Botany*, *58*(4), 797–806. https://doi.org/10.1093/jxb/erl208

Maurel, M., Robin, C., Simonneau, T., Loustau, D., Dreyer, E., & Desprez-Loustau, M.-L. (2004). Stomatal conductance and root-to-shoot signalling in chestnut saplings exposed to Phytophthora cinnamomi or partial soil drying. *Functional Plant Biology*, *31*, 41–51. https://doi.org/10.1071/FP03133

McDonald, J. G., Wong, E., & White, G. P. (2000). Differentiation of Tilletia taxa by rep-PCR genomic fingerprinting. *EPPO Bulletin*, *30*(3–4), 549–553. https://doi.org/10.1111/j.1365-2338.2000.tb00945.x

Mei, Z., Yang, L., Khan, M. A., Yang, M., Wei, C., Yang, W., Peng, X., Tania, M., Zhang, H., Li, X., & Fu, J. (2014). Genotyping of Ganoderma species by improved random amplified polymorphic DNA (RAPD) and inter-simple sequence repeat (ISSR) analysis. *Biochemical Systematics and Ecology*, *56*, 40–48. https://doi.org/10.1016/j.bse.2014.04.012

Mercière, M., Laybats, A., Carasco-Lacombe, C., Tan, J. S., Klopp, C., Durand-Gasselin, T., Alwee, S. S. R. S., Camus-Kulandaivelu, L., & Breton, F. (2015). Identification and development of new polymorphic microsatellite markers using genome assembly for Ganoderma boninense, causal agent of oil palm basal stem rot disease. *Mycological Progress*, *14*, 103. https://doi.org/10.1007/s11557-015-1123-2

Midot, F., Lau, S. Y. L., Wong, W. C., Tung, H. J., Yap, M. L., Lo, M. L., Jee, M. S., Dom, S. P., & Melling, L. (2019). Genetic diversity and demographic history of

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.edu.id/

Ganoderma boninense in oil palm plantations of Sarawak, Malaysia inferred from ITS regions. *Microorganisms*, *7*, 464. https://doi.org/10.3390/microorganisms7100464

Miller, R. N. G., Holderness, M., Bridge, P. D., Chung, G. F., & Zakaria, M. H. (1999). Genetic diversity of Ganoderma in oil palm plantings. *Plant Pathology*, *48*, 595–603. https://doi.org/10.1046/j.1365-3059.1999.00390.x

Mishra, R. K., Pandey, B. K., Pathak, N., & Zeeshan, M. (2015). BOX-PCR- and ERIC-PCR-based genotyping and phylogenetic correlation among Fusarium oxysporum isolates associated with wilt disease in Psidium guajava L. *Biocatalysis and Agricultural Biotechnology*, *4*(1), 25–32. https://doi.org/10.1016/j.bcab.2014.09.012

Mohan, D., Namasivayam, P., Saidi, N. B., & Ho, C. L. (2022). Temporal expression of defense-related genes in Ganoderma-infected oil palm roots. *Trees - Structure and Function*, *36*(3), 1029–1038. https://doi.org/10.1007/s00468-022-02269-1

Moncalvo, J.-M., & Ryvarden, L. (1997). *A Nomenclatural Study of the Ganodermataceae Donk*. Benjamin Sats of Trykk.

Naher, L., Yusuf, U. K., Ismail, A., Tan, S. G., & Mondal, M. M. A. (2013). Ecological status of Ganoderma and basal stem rot disease of oil palms (Elaeis guineensis Jacq.). *Australian Journal of Crop Science*, *7*(11), 1723–1727.

Nguyen, T.-T., Bui, T.-T., Pham, B.-P., Nguyen, H.-T., Ngo, X.-B., La, V.-H., & Nguyen, T.-D. (2021). Identification of ganoderma lucidum (curtis) p. karst. species isolated from ironwood (erythrophleum fordii oliver) in viet nam act through by its1 sequence and phylogenetic analysis. *Plant Cell Biotechnology and Molecular Biology*, *22*(17–18), 59–70.

Nguyen, T. T. T., Nguyen, H. D., Bui, A. T., Pham, K. H. T., Van, K. T. P., Tran, L. T., & Tran, M. H. (2023). Phylogenetic analysis and morphology of Ganoderma multipileum , a Ganoderma species associated with dieback of the metropolitan woody plant Delonix regia (Boj . ex. *Science Progress*, *106*(3), 1–18. https://doi.org/10.1177/00368504231195503

Nguyen, T. T. T., Pham, P. T. V., Nguyen, V. A. T., Nguyen, T. T. T., Tran, L. T., Truong, P. C. H., & Tran, M. H. (2025). Taxonomic characterization and cytotoxic potential of Vietnamese Ganoderma ellipsoideum against human breast cancer MCF-7 cells. *PLoS ONE*, *20*(11), e0336024. https://doi.org/10.1371/journal.pone.0336024

Nugroho, S., Rahmadi, H. Y., & Simamora, A. N. (2025). 1H NMR metabolomic profiling of resistant and susceptible oil palm root tissues in response to Ganoderma boninense at the nursery stage. *Scientific Reports*, *15*, 16784. https://doi.org/https://doi.org/10.1038/s41598-025-01691-y 1

Nurazah, Z., Idris, A. S., Kushairi, A., Din, A. M., Abrizah, O., & Ramli, U. S. (2017). Metabolomics unravel differences between Cameroon Dura and deli Dura oil palm (Elaeis guineensis Jacq.) genetic backgrounds against Basal stem rot. *Journal of Oil Palm Research*, *29*(2), 227–241. https://doi.org/10.21894/jopr.2017.2902.07

Nurazah, Z., Othman, A., Sundram, S., Ibrahim, M. H., Faudzi, S. M. M., & Ismail, I. S. (2026). 1H NMR-based metabolomic analysis reveals the time-dependent and pH-modulation on the metabolite secretion of Ganoderma boninense and

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Ganoderma tornatum. *Physiological and Molecular Plant Pathology*, *142*, 103100. https://doi.org/10.1016/j.pmpp.2025.103100

Nurlaelita, K., Wibowo, A., & Widiastuti, A. (2024). Identification and Characterization Colletotrichum spp. Causing Mango Dieback in Indonesia. *Plant Pathology Journal*, *40*(4), 399–407. https://doi.org/10.5423/PPJ.NT.04.2024.0061

Nusaibah, S. A., Rajinder, S., & Idris, A. S. (2010). Somatic incompatibility and aflp analysis of four species of ganoderma isolated from oil palm. *Journal of Oil Palm Research*, *22*(AUGUST), 814–821.

Onsori, H., Zamani, M. R., Motallebi, M., & Zarghami, N. (2005). Identification of over producer strain of endo-β-1,4-glucanase in Aspergillus Species: Characterization of crude carboxymethyl cellulase. *African Journal of Biotechnology*, *4*(1), 26–30.

Othman, N. Q., Sulaiman, S., Lee, Y. P., & Tan, J. S. (2019). Transcriptomic data of mature oil palm basal trunk tissue infected with Ganoderma boninense. *Data in Brief*, *25*, 104288. https://doi.org/10.1016/j.dib.2019.104288

Palanna, K. B., Koti, P. S., Basavaraj, S., Boraiah, B., & Narendrappa, T. (2022). Morphological and molecular diversity of Ganoderma spp. causal agent of basal stem rot of coconut in Southern dry tracts of Karnataka. *Journal of Horticultural Sciences*, *17*(2), 436–447. https://doi.org/10.24154/jhs.v17i2.1352

Pancoro, A., Karima, E., Apriyanto, A., & Effendi, Y. (2022). 1H NMR metabolomics analysis of oil palm stem tissue infected by Ganoderma boninense based on field severity Indices. *Scientific Reports*, *12*(1), 1–13. https://doi.org/10.1038/s41598-022-25450-5

Pang, Z., Chen, J., Wang, T., Gao, C., Li, Z., Guo, L., Xu, J., & Cheng, Y. (2021). Linking Plant Secondary Metabolites and Plant Microbiomes: A Review. *Frontiers in Plant Science*, *12*(March), 621276. https://doi.org/10.3389/fpls.2021.621276

Paterson, R. R. M. (2019). Ganoderma boninense disease of oil palm to significantly reduce production after 2050 in sumatra if projected climate change occurs. *Microorganisms*, *7*(1), 4–6. https://doi.org/10.3390/microorganisms7010024

Peng, S., Yap, C., Ren, P., & Chai, E. (2019). Effects of Environment and Nutritional Conditions on mycelial growth of Ganoderma boninense. *International Journal of Oil Palm*, *2*(3), 95–107. https://doi.org/10.35876/ijop.v2i3.43

Pilotti, C. A. (2005). Stem rots of oil palm caused by Ganoderma boninense: Pathogen biology and epidemiology. *Mycopathologia*, *159*(1), 129–137. https://doi.org/10.1007/s11046-004-4435-3

Pilotti, C. A., Gorea, E. A., & Bonneau, L. (2018). Basidiospores as sources of inoculum in the spread of Ganoderma boninense in oil palm plantations in Papua New Guinea. *Plant Pathology*, *67*(9), 1841–1849. https://doi.org/10.1111/ppa.12915

Pilotti, C. A., Killah, G., Rama, D., Gorea, E. A., & Mudge, A. M. (2021). A preliminary study to identify and distinguish southern tropical populations of Ganoderma boninense from oil palm via mating assays, sequence data, and microsatellite markers. *Mycologia*, *113*(3), 574–585. https://doi.org/10.1080/00275514.2020.1858687

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Pilotti, C. A., Sanderson, F. R., & Aitken, E. A. B. (2003). Genetic structure of a population of Ganoderma boninense on oil palm. *Plant Pathology*, *52*(4), 455–463. https://doi.org/10.1046/j.1365-3059.2003.00870.x

Pilotti, C. A., Sanderson, F. R., Aitken, E. A. B., & Armstrong, W. (2004). Morphological variation and host range of two Ganoderma species from Papua New Guinea. *Mycopathologia*, *158*, 251–265. https://doi.org/10.1023/B:MYCO.0000041833.41085.6f

Pramunadipta, S., Widiastuti, A., Wibowo, A., & Priyatmojo, A. (2022). rep-PCR analysis of Fusarium proliferatum causing sheath rot disease and its relationship to light, pH, temperature and rice varieties. *Archives of Phytopathology and Plant Protection*, *55*(8), 973–990. https://doi.org/10.1080/03235408.2022.2081484

Pramunadipta, S., Widiastuti, A., Wibowo, A., & Priyatmojo, A. Z. (2021). Genetic diversity of the pathogenic fungus Sarocladium oryzae causing sheath rot on rice using rep-PCR. *IOP Conference Series: Earth and Environmental Science*, *667*, 012057. https://doi.org/10.1088/1755-1315/667/1/012057

Pratama, Y., Wibowo, A., Widiastuti, A., Subandiyah, S., Widinugraheni, S., & Rep, M. (2018). Evaluation of Some Specific Primer Sets Development for Detecting Fusarium oxysporum f. sp. cubense Tropic Race 4 (Foc TR4) Originating from Indonesia. *Jurnal Perlindungan Tanaman Indonesia*, *22*(1), 82. https://doi.org/10.22146/jpti.25037

Proels, R. K., & Hückelhoven, R. (2014). Cell-wall invertases , key enzymes in the modulation of plant metabolism during defence responses. *Molecular Plant Pathology*, *15*(8), 858–864. https://doi.org/10.1111/mpp.12139

Purba, A., Basyuni, M., Putri, L. A. P., Chalil, D., Hayati, R., Arifiyanto, D., & Syahputra, I. (2019). Sequence analysis of Ganoderma boninense isolates from oil palm. *IOP Conference Series: Earth and Environmental Science*, *260*(1). https://doi.org/10.1088/1755-1315/260/1/012172

Purba, A., Hayati, R., Putri, L. A. P., Chalil, D., Afandi, D., Syahputra, I., & Basyuni, M. (2020). Genetic diversity and structure of ganoderma boninense isolates from oil palm and other plantation crops. *Biodiversitas*, *21*(2), 451–456. https://doi.org/10.13057/biodiv/d210204

Putranto, R. A., Syaputra, I., & Budiani, A. (2016). Differential Gene Expression In Oil Palm Varieties Susceptible And Tolerant To Ganoderma. *Proceedings of the 6th Indonesian Biotechnology Conference Enhancing Industrial Competitiveness through Biotechnology Innovation (Surakarta: Universitas Sebeleas Maret)*, *233*(September), 6–7. http://www.ebi.ac.uk/ena

Putri, S. P., & Fukusaki, E. (2016). *Mass Spectrometry-Based Metabolomics: A Practical Guide*. https://doi.org/https://doi.org/10.1201/b17793

Rahmadi, H. Y., Syukur, M., Widodo, Suwarno, W. B., Wening, S., Simamora, A. N., & Nugroho, S. (2024). 1H NMR analysis of metabolites from leaf tissue of resistant and susceptible oil palm breeding materials against Ganoderma boninense. *Metabolomics*, *20*, 89. https://doi.org/https://doi.org/10.1007/s11306-024-02160-9

Rahman, M. M., Keya, S. S., Sahu, A., Gupta, A., Dhingra, A., Tran, L. S. P., & Mostofa, M. G. (2024). Acetic acid: a cheap but chief metabolic regulator for abiotic stress tolerance in plants. *Stress Biology*, *4*, 34.

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

https://doi.org/10.1007/s44154-024-00167-9

Rakib, M. R. M., Bong, C. F. J., Khairulmazmi, A., & Idris, A. S. (2014). Genetic and morphological diversity of Ganoderma species isolated from infected oil palms (Elaeis guineensis). *International Journal of Agriculture and Biology*, *16*(4), 691–699.

Rakib, M. R. M., Bong, C., Khairulmazmi, A., & Idris, A. S. (2015). Aggressiveness of Ganoderma boninense and G. zonatum Isolated from Upper- and Basal Stem Rot ff Oil Palm (Elaeis Guineensis) in Malaysia. *Journal of Oil Palm Research*, *27*(May 2016), 229–240.

Ramzi, A. B., Me, M. L. C., Ruslan, U. S., Baharum, S. N., & Muhammad, N. A. N. (2019). Insight into plant cell wall degradation and pathogenesis of Ganoderma boninense via comparative genome analysis. *PeerJ*, *2019*(12). https://doi.org/10.7717/peerj.8065

Rees, R. W., Flood, J., Hasan, Y., Potter, U., & Cooper, R. M. (2009). Basal stem rot of oil palm (Elaeis guineensis); Mode of root infection and lower stem invasion by Ganoderma boninense. *Plant Pathology*, *58*(5), 982–989. https://doi.org/10.1111/j.1365-3059.2009.02100.x

Rees, R. W., Flood, J., Hasan, Y., Wills, M. A., & Cooper, R. M. (2012). Ganoderma boninense basidiospores in oil palm plantations: Evaluation of their possible role in stem rots of Elaeis guineensis. *Plant Pathology*, *61*(3), 567–578. https://doi.org/10.1111/j.1365-3059.2011.02533.x

Righetti, L., Bhandari, D. R., Rolli, E., Tortorella, S., Bruni, R., Dall'Asta, C., & Spengler, B. (2021). Mycotoxin Uptake in Wheat — Eavesdropping Fusarium Presence for Priming Plant Defenses or a Trojan Horse to Weaken Them? *Frontiers in Plant Science*, *12*(July), 1–11. https://doi.org/10.3389/fpls.2021.711389

Rojas, C. M., Senthil-Kumar, M., Tzin, V., & Mysore, K. S. (2014). Regulation of primary plant metabolism during plant-pathogen interactions and its contribution to plant defense. *Frontiers in Plant Science*, *5*(FEB), 1–12. https://doi.org/10.3389/fpls.2014.00017

Romero-González, R. R., Mirnezhad, M., Leiss, K. A., Choi, Y. H., & Klinkhamer, P. G. L. (2010). A metabolomics approach to thrips resistance in tomato. *Phytochem. Anal.*, *21*, 110–117. https://openaccess.leidenuniv.nl/handle/1887/17920

Rozali, N. L., Yarmo, M. A., Idris, A. S., Kushairi, A., & Ramli, U. S. (2017). Metabolomics differentiation of oil palm (Elaeis guineensis Jacq.) spear leaf with contrasting susceptibility to Ganoderma boninense. *Plant OMICS*, *10*(2), 45–52. https://doi.org/10.21475/poj.10.02.17.pne364

Sahebi, M., Hanafi, M. M., Mohidin, H., Rafii, M. Y., Azizi, P., Idris, A. S., Fariz, A., Abiri, R., Taheri, S., & Moradpoor, M. (2018). Antioxidant Enzyme Activities and Secondary Metabolite Profiling of Oil Palm Seedlings Treated with Combination of NPK Fertilizers Infected with Ganoderma boninense. *BioMed Research International*, *2018*, 1494157. https://doi.org/10.1155/2018/1494157

Sahebi, M., Hanafi, M. M., van Wijnen, A. J., Akmar, A. S. N., Azizi, P., Idris, A. S., Taheri, S., & Foroughi, M. (2017). Profiling secondary metabolites of plant defence mechanisms and oil palm in response to Ganoderma boninense attack.

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

International Biodeterioration and Biodegradation, *122*, 151–164. https://doi.org/10.1016/j.ibiod.2017.04.016

Saptarini, N. M., & Hadisoebroto, G. (2017). The activity of cellulase Enzymes of Ganoderma applanatum and Ganoderma tropicum. *Journal of Applied Pharmaceutical Science*, *7*(4), 134–137. https://doi.org/10.7324/JAPS.2017.70419

Sedigheh, H. G., Mortazavian, M., Norouzian, D., Atyabi, M., Akbarzadeh, A., Hasanpoor, K., & Ghorbani, M. (2011). Oxidative stress and leaf senescence. *BMC Research Notes*, *4*(1), 477. https://doi.org/10.1186/1756-0500-4-477

Semangun, H. (2008). *Penyakit-penyakit Tanaman Perkebunan di Indonesia*. Gadjah Mada University Press.

Setyahadi, S., Putri, S. F., & Suhartono. (2019). Screening microbe producing chitinase for inhibiting Ganoderma boninense Screening microbe producing Ganoderma boninense chitinase for inhibiting. *IOP Conf. Series: Earth and Environmental Science*, *230*, 012100. https://doi.org/10.1088/1755-1315/230/1/012100

Shalini, S., Singla, A., Goyal, M., Kaur, V., & Kumar, P. (2018). Omics in Agriculture: Applications, Challenges and Future Perspectives. In *Crop Improvement for Sustainability* (Number January). https://www.researchgate.net/publication/325390380_Omics_in_Agriculture_Applications_Challenges_and_Future_Perspectives

Sharma, V. (2013). Pathogenesis related defence functions of plant chitinases and β-1,3-glucanases. *Vegetos*, *26*(2s), 205–218. https://doi.org/10.5958/j.2229-4473.26.2s.141

Silitonga, Y. R., Heryanto, R., Taufik, N., Indrayana, K., Nas, M., & Kusrini, N. (2020). *Budidaya Kelapa Sawit & Varietas Kelapa Sawit*.

Simamora, A. N., & Wening, S. (2021). Kajian Metabolit Sebagai Pendukung Program Pemuliaan Kelapa Sawit. *WARTA Pusat Penelitian Kelapa Sawit*, *26*(3), 162–177. https://warta.iopri.org/index.php/Warta/article/view/66%0Ahttps://warta.iopri.org/index.php/Warta/article/download/66/42

Suryantini, R., & Wulandari, R. S. (2018). Diversity of Ganoderma pathogen in Pontianak , West Kalimantan : Characteristics , virulence and ability to infect Acacia mangium seedlings. *Biodiversitas*, *19*(2), 465–471. https://doi.org/10.13057/biodiv/d190213

Susanto, A., Prasetyo, A. E., Priwiratama, H., Wening, S., & Surianto, S. (2013). Ganoderma boninense Penyebab Penyakit Busuk Batang Atas Kelapa Sawit. *Jurnal Fitopatologi Indonesia*, *9*(4), 123–126. https://doi.org/10.14692/jfi.9.4.123

Suwandi, S., Alesia, M., Munandar, R. P., Fadli, R., Suparman, S., Irsan, C., & Muslim, A. (2024). The suppression of Ganoderma boninense on oil palm under mixed planting with taro plants. *Biodiversitas*, *25*(3), 1143–1150. https://doi.org/10.13057/biodiv/d250329

Takagi, H., Ishiga, Y., Watanabe, S., Konishi, T., Egusa, M., Akiyoshi, N., Matsuura, T., Mori, I. C., Hirayama, T., Kaminaka, H., Shimada, H., & Sakamoto, A. (2016). Allantoin, a stress-related purine metabolite, can activate jasmonate signaling in

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

a MYC2-regulated and abscisic acid-dependent manner. *Journal of Experimental Botany*, *67*(8), 2519–2532. https://doi.org/10.1093/jxb/erw071

Tardivel, P. J. C., Canlet, C., Lefort, G., Tremblay-Franco, M., Debrauwer, L., Concordet, D., & Servien, R. (2017). ASICS: an automatic method for identification and quantification of metabolites in complex 1D 1H NMR spectra. *Metabolomics*, *13*(10). https://doi.org/10.1007/s11306-017-1244-5

Teh, C., Pang, C., Tor, X., Ho, P., & Lim, Y. (2019). Molecular cloning and functional analysis of a necrosis and ethylene inducing protein (NEP) from Ganoderma boninense. *Physiological and Molecular Plant Pathology*, *106*(December 2018), 42–48. https://doi.org/10.1016/j.pmpp.2018.12.003

Turland, N. J., Wiersema, J. H., Barrie, F. R., Greuter, W., Hawksworth, D. L., Herendeen, P. S., Knapp, S., Kusber, W.-H., Li, D.-Z., Marhold, K., May, T. W., McNeill, J., Monro, A. M., Prado, J., Price, M. J., & Smith, G. F. (2015). International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code). In *Regnum Vegetabile* (Vol. 158, Number July 2017). https://doi.org/https://doi.org/10.12705/Code.2018

Turner, P. D. (1981). Oil Palm Diseases and Disorders. In *Brittonia*. Oxford Univ. Press. https://doi.org/10.2307/2806712

Utomo, C., Werner, S., Niepold, F., & Deising, H. B. (2005). Identification of Ganoderma, the causal agent of basal stem rot disease in oil palm using a molecular method. *Mycopathologia*, *159*(1), 159–170. https://doi.org/10.1007/s11046-004-4439-z

Van Der Plank, J. E. (1963). *Plant Diseases: Epidemics and Control*. Academic press.

Van der Rest, B., Boisson, A. M., Gout, E., Bligny, R., & Douce, R. (2002). Glycerophosphocholine metabolism in higher plant cells. Evidence of a new glyceryl-phosphodiester phosphodiesterase. *Plant Physiology*, *130*(1), 244–255. https://doi.org/10.1104/pp.003392

Van Emon, J. M. (2016). The Omics Revolution in Agricultural Research. *Journal of Agricultural and Food Chemistry*, *64*(1), 36–44. https://doi.org/10.1021/acs.jafc.5b04515

Vignoli, A., Cacciatore, S., & Tenori, L. (2025). Deriving three one dimensional NMR spectra from a single experiment through machine learning. *Nature Communication*, *16*, 10159. https://doi.org/https://doi.org/10.1038/s41467-025-65294-x

Wang, H., Ma, Y., Jin, M., Wang, C., Wang, K., Zheng, Y., Guo, L., Liu, X., Cui, Y., & Zhang, H. (2026). Plant Physiology and Biochemistry Emerging trends in protein post-translational modifications of lysine associated with plant stress and development. *Plant Physiology and Biochemistry*, *233*, 111232. https://doi.org/10.1016/j.plaphy.2026.111232

Wiratmoko, D., Prasetyo, A. E., Jatmiko, R. H., Yusuf, M. A., & Rahutomo, S. (2018). Identification of Ganoderma boninense Infection Levels on Oil Palm Using Vegetation Index. *International Journalof Oil Palm*, *1*(3), 110–120.

Wong, L.-C., Bong, C.-F. J., & Idris, A. S. (2012). Ganoderma Species Associated with Basal Stem Rot Disease of Oil Palm. *American Journal of Applied Sciences*, *9*(6), 879–885. https://doi.org/https://doi.org/10.3844/ajassp.2012.879.885

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Wong, W. C., Goh, Y. K., Wong, C. K., Goh, Y. K., Marzuki, N. F., Choo, C. H. Y., & Tung, H. J. (2024). Genetic Structure of Ganoderma boninense Populations Associated with Oil Palm at Neighboring Fields with Different Planting Ages in Malaysia. *Plant Disease*, *108*(7), 1982–1986. https://doi.org/10.1094/PDIS-07-23-1426-SC

Wong, W. C., Tung, H. J., Fadhilah, M. N., Midot, F., Lau, S. Y. L., Melling, L., Astari, S., Hadziabdic, Trigiano, R. N., Goh, K. J., & Goh, Y. K. (2021). Genetic diversity and gene flow amongst admixed populations of Ganoderma boninense, causal agent of basal stem rot in African oil palm (Elaeis guineensis Jacq.) in Sarawak (Malaysia), Peninsular Malaysia, and Sumatra (Indonesia). *Mycologia*, *113*(5), 902–917. https://doi.org/10.1080/00275514.2021.1884815

Xing, J., Sun, Y., Han, Y., Cui, B., & Dai, Y. (2018). Morphological and molecular identification of two new Ganoderma species on Casuarina equisetifolia from China. *MycoKeys*, *34*, 93–108. https://doi.org/10.3897/mycokeys.34.22593

Yoneda, K., Nagano, R., Mikami, T., Sakuraba, H., Fukui, K., Araki, T., & Ohshima, T. (2020). Enzyme and Microbial Technology Catalytic properties and crystal structure of UDP-galactose 4-epimerase-like L -threonine 3-dehydrogenase from Phytophthora infestans. *Enzyme and Microbial Technology*, *140*(June), 109627. https://doi.org/10.1016/j.enzmictec.2020.109627

Zain, N., Seman, I. A., Kushairi, A., & Ramli, U. S. (2013). Metabolite profiling of oil palm towards understanding basal stem rot (BSR) disease. *Journal of Oil Palm Research*, *25*(1), 58–71.

Zakaria, L., Kulaveraasingham, H., Guan, T. S., Abdullah, F., & Wan, H. Y. (2005). Random amplified polymorphic DNA (RAPD) and random amplified microsatellite (RAMS) of Ganoderma from infected oil palm and coconut stumps in Malaysia. *Asia-Pacific Journal of Molecular Biology and Biotechnology*, *13*(1), 23–34.

Zeiss, D. R., Steenkamp, P. A., Piater, L. A., & Dubery, I. A. (2021). Altered metabolomic states elicited by Flg22 and FlgII-28 in Solanum lycopersicum : intracellular perturbations and metabolite defenses. *BMC Plant Biology*, *21*, 429. https://doi.org/https://doi.org/10.1186/s12870-021-03200-5

Zhang, H., Murzello, C., Sun, Y., Kim, M., Xie, X., Jeter, R. M., Zak, J. C., Dowd, S. E., & Paré, P. W. (2010). Choline and Osmotic-Stress Tolerance Induced in Arabidopsis by the Soil Microbe Bacillus subtilis (GB03). *Molecular Plant-Microbe Interactions*, *23*(8), 1097–1104. https://doi.org/doi:10.1094 /MPMI -23-8-1097

Zhang, K., Cao, H., Ma, Y., Si, H., Zang, J., Bai, H., Yu, L., Pang, X., Zhou, F., Xing, J., & Dong, J. (2022). Global analysis of lysine 2-hydroxyisobutyrylation during Fusarium graminearum infection in maize. *Front. Plant Sci.*, *13*, 1000039. https://doi.org/10.3389/fpls.2022.1000039

Zhang, K., Lyu, W., Gao, Y., Zhang, X., Sun, Y., & Huang, B. (2020). Choline-Mediated Lipid Reprogramming as a Dominant Salt Tolerance Mechanism in Grass Species Lacking Glycine Betaine. *PlantCell Physiol.*, *61*(12), 2018–2030. https://doi.org/10.1093/pcp/pcaa116

Zhang, R., Yang, X., Jiang, Y., Wu, P., Wang, L., Li, Z., Zhang, X., Shen, X., & Chen, H. (2026). Taurine as a multifunctional biostimulant in plants: From physiological

UNIVERSITAS
GADJAH MADA
Karakterisasi Patogen dan Profil Senyawa Metabolit Terkait Patosistem Kelapa Sawit-Ganoderma
Rachmad Saputra, Prof. Achmadi Priyatmojo, M.Sc., Ph.D., IPU. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.; Prof. Ani Widiastuti,
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

roles to biochemical mechanisms and emerging applications. *Industrial Crops and Products*, *248*(April), 123619. https://doi.org/10.1016/j.indcrop.2026.123619

Zheng, C., Zhu, J., Yang, X., & Fu, B. (2022). Short Communication: Genetic diversity of walnut blight-associated bacteria from China using rep-PCR. *Biodiversitas*, *23*(11), 5681–5686. https://doi.org/10.13057/biodiv/d231118

Zheng, L., Jia, D., Fei, X., Luo, X., & Yang, Z. (2009). An assessment of the genetic diversity within Ganoderma strains with AFLP and ITS PCR-RFLP. *Microbiological Research*, *164*(3), 312–321. https://doi.org/10.1016/j.micres.2007.02.002

Zhou, L., Cao, Y., Wu, S., Vlasák, J., Li, D., Li, M., & Dai, Y. (2015). Phytochemistry global diversity of the Ganoderma lucidum complex (Ganodermataceae , Polyporales) inferred from morphology and multilocus phylogeny. *Phytochemistry*, *114*, 7–15. https://doi.org/10.1016/j.phytochem.2014.09.023

Zhou, X. W., Liu, Y., Guo, M. Y., Su, K. Q., & Zhang, Y. M. (2016). Species clarification of the widely cultivated Ganoderma in China based on rDNA and FIP gene sequence analysis. *International Journal of Agriculture and Biology*, *18*(5), 932–938. https://doi.org/10.17957/IJAB/15.0189

Zhu, Y., Zong, Y., Liang, W., Kong, R., Gong, D., Han, Y., Li, Y., Bi, Y., & Prusky, D. (2022). Sorbitol immersion accelerates the deposition of suberin polyphenolic and lignin at wounds of potato tubers by activating phenylpropanoid metabolism. *Scientia Horticulturae*, *297*(February), 110971. https://doi.org/10.1016/j.scienta.2022.110971

Zulkifli, Y., Alitheen, N. B., Son, R., Raha, A. R., Samuel, L., Yeap, S. K., & Nishibuchi, M. (2009). Random amplified polymorphic DNA-PCR and ERIC PCR analysis on Vibrio parahaemolyticus isolated from cockles in Padang, Indonesia. *International Food Research Journal*, *16*(2), 141–150.