UNIVERSITAS
GADJAH MADA
**Identifikasi dan Analisis Ekspresi Gen Efektor Ganoderma boninense penyebab Penyakit Busuk Batang
pada Tanaman Kelapa Sawit**
Fidia Hudzaifah Akmal, Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.
**Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/**

# DAFTAR PUSTAKA

Abdollahzadeh, J., Zolfaghari, Sajedeh. 2014. Efficiency of Rep-PCR Fingerprinting as A Useful Technique for Molecular Typing of Plant Pathogenic Fungal Species: Botryosphaeriaceae Species as A Case Study. *FEMS Microbiology Letters*, 361(2), 144–157.

Abdullah, S.N.A., Akhtar, M.S. 2016. *Plant and Necrotrophic Fungal Pathogen Interaction: Mechanism and Mode of Action*. In: Plant, Soil and Microbes. Cham: Springer. p. 29–53.

Ahmed, S., Kim, Y. 2018. Differential Immunosuppression by Inhibiting PLA2 Affects Virulence of *Xenorhabdus hominickii* and *Photorhabdus temperata. J. Invertebr. Pathol*. 157:136–46.

Ali, S., Ganai, B.A., Kamili, A.N., Bhat, A.A., Mir, Z.A, Bhat, J.A., Tyagi, A., Islam, S. T., Mushtaq, M., Yadav, P., Rawat, S., Grover, A. 2018. Pathogenesis-related Proteins and Peptides as Promising Tools for Engineering Plants with Multiple Stress Tolerance. *Microbiol. Res.* 212–213:29–37.

Alves, A., Phillips, A.J.L., Henriques, I., Correia, A. 2007. Rapid Differentiation of Species of Botryosphaeriaceae by PCR Fingerprinting. *Res Microbiol* 158: 112–121.

Artika, I.M., Dewi, Y.P., Nainggolan, I.M., Siregar, J.E., Antonjaya, U. 2022. Real-Time Polymerase Chain Reaction: Current Techniques, Applications, and Role in COVID-19 Diagnosis. *Genes*. 13(12).

Badotti, F., de Oliveira, F.S., Garcia, C.F., Vas, A.B.M., Fonseca, P.L.C., Nahum, L.A., Oliveira, G., Góes-Neto, A. 2017. Effectiveness of ITS and Sub-regions as DNA Barcode Markers for The Identification of Basidiomycota (Fungi). *BMC Microbiol* 17, 42.

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 *Ganoderma boninense* Provides Novel Insights on Fungal Transition from Biotrophic to Necrotrophic Phase. BMC Plant Biol. 18(1):377.

Bharudin, I., Wahab, A.F.F., Samad, M.A., Xin, Yie, N., Zairun, M.A., Abu Bakar, F.D., Abdul, M.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 (Basel).* 11(2):251.

Bhaskar, R.T., Chopperla, R., Prathi, N.B., Balakrishnan, M., Prakasam, V., Laha, G.S., Balachandran, S.M., Mangrauthia, S.K. 2020. A Comprehensive Gene Expression Profile of Pectin Degradation Enzymes Reveals the Molecular Events during Cell Wall Degradation and Pathogenesis of Rice Sheath Blight Pathogen Rhizoctonia solani AG1-IA. *J Fungi (Basel)*. 6(2).

Baldwin, B.G. 1992. Phylogenetic Utility of The Internal Transcribed Spacers of Nuclear Ribosomal DNA in Plants: An Example from The Compositae. *Mol Phylogenet Evol.* 1; 1(1): 3–16.

Camagna, M., Takemoto, D. 2018. *Hypersensitive Response in Plants. In: eLS, John Wiley & Sons*, Ltd:Chichester; p. 1–7.

UNIVERSITAS
GADJAH MADA
**Identifikasi dan Analisis Ekspresi Gen Efektor Ganoderma boninense penyebab Penyakit Busuk Batang
pada Tanaman Kelapa Sawit**
Fidia Hudzaifah Akmal, Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.
**Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/**

Cantu, D., Blanco-Ulate, B., Yang, L., Labavitch, J.M., Bennett, A.B., Powell, A.L.T. 2009. Ripening-Regulated Susceptibility of Tomato Fruit to *Botrytis cinerea* Requires NOR but Not RIN or Ethylene. *Plant Physiol*. 150(3):1434–49.

Capodicasa, C., Vairo, D., Zabotina, O., McCartney, L., Caprari, C., Mattei, B., Manfredini, C., Aracri, B., Benen, J., Knox, J.P., Lorenzo, G.D., Cervone, F. 2004. Targeted Modification of Homogalacturonan by Transgenic Expression of A Fungal Polygalacturonase Alters Plant Growth. *Plant Physiol*. 135(3):1294–1304.

Chen, Y., Wu, X., Xu, C., Huang, J., Zhang, L., Qiu, P., Zheng, D., Chen, W., Zhang, S. 2025. Pathogen Virulence Genes: Advances, Challenges and Future Directions in Infectious Disease Research (Review). *Int J Mol Med.* 56(5):173.

Chong, K.P., Dayou, J., Alexander, A. 2017. *Control Methods of G. boninense in Oil Palm Industry. In Detection and Control of Ganoderma Boninense in Oil Palm Crop*, pp. 21–30. Cham: Springer International Publishing.

Conesa, A., Punt, P.J., van den Hondel, C.A.M.J.J. 2002. Fungal Peroxidases: Molecular Aspects and Applications. *J. Biotechnol*. 93(2):143–58.

Dhillon, B., Hamelin, R.C., Rollins, J.A. 2021. Transcriptional Profile of Oil Palm Pathogen, *Ganoderma boninense*, Reveals Activation of Lignin Degradation Machinery and Possible Evasion of Host Immune Response. *BMC Genomics*. 22(1):326.

Dong, Z., Wang, Z. 2011. Isolation and Characterization of An Exopolygalacturonase from *Fusarium oxysporum* f.sp. cubense Race 1 and Race 4. *BMC Biochem* 12, 51.

Dunford, H.B. 1999. *Heme Peroxidases, 1st edn*. Wiley-VCH, New York.

Edy, A., Anshary, A., Basir-Cyio, M., Mahfudz, I. L., Kadir, S. R. A., Mahmud, S. 2020. Incidence and Severity of *Ganoderma* Rot Disease in Tropical Land-Use Systems and Their Virulence to Palm Oil. *Plant Pathology Journal.* 19(2):98– 105.

Elfina, Y., Irfandri, Sabirunah, A., Ningsih, W. 2025. Identification of The Causes of Base Rot Disease of Palm Oil in Two Villages in Kampar and Siak Districts of Riau Province. *JUATIKA*. 7(1).

Ferrari, S., Galletti, R., Pontiggia, D., Manfredini, C., Lionetti, V., Bellincampi, D., Cervone, F., Lorenzo, D.G. 2008. Transgenic Expression of a Fungal endo-Polygalacturonase Increases Plant Resistance to Pathogens and Reduces Auxin Sensitivity. *Plant Physiology*, Volume 146, Issue 2, Pages 323–324.

Fontana, R.C., Salvador, S., da Silveira, M.M. 2005. Influence of Pectin and Glucose on Growth and Polygalacturonase Production By *Aspergillus niger* in Solid-State Cultivation. *J. Ind. Microbiol. Biotechnol*. 32(8):371–77.

FreihorsT, D., Fowler, T.J., Bartholomew, K., Raudaskoski, M., Horton, J.S., Kothe, E. 2016. *13 The Mating-Type Genes of the Basidiomycetes. In Growth, Differentiation and Sexuality*, ed. J Wendland, pp. 329–49. Cham: Springer International Publishing.

UNIVERSITAS
GADJAH MADA
**Identifikasi dan Analisis Ekspresi Gen Efektor Ganoderma boninense penyebab Penyakit Busuk Batang
pada Tanaman Kelapa Sawit**
Fidia Hudzaifah Akmal, Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.
**Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/**

Gillings, M. R., & Holley, M. 1997. Repetitive Element PCR Fingerprinting (REP-PCR) Using Enterobacterial Repetitive Intergenic Consensus (ERIC) Primers is Not Necessarily Directed at ERIC Elements. *Letters in Applied Microbiology*, 25(1), 17–21.

Green, S. J., Venkatramanan, R., & Naqib, A. 2015. Deconstructing The Polymerase Chain Reaction: Understanding and Correcting Bias Associated with Primer Degeneracies And Primer-Template Mismatches. *PLOS ONE*, 10(5), e0128122.

Guleria, P., Mahajan, M., Bhardwaj, J., Yadav, S.K. 2011. Plant small RNAs: Biogenesis, Mode of Action and Their Roles in Abiotic Stresses. *Genomics Proteomics Bioinformatics*. 9(6):183–99.

Hamid, S., Ho, C.L., Abdullah, S.N.A., Low, E.T.L., Nagappan, J., Wong, M.Y. 2024. Characterisation and Expression Analyses of Two Putative Cerato-Platanin Proteins Isolate from Ganoderma boninense Pat. *Physiological and Molecular Plant Pathology.* 131:102289.

Hamzah, A., Saputra, R., Puspita, F., Nasrul, B., Irfandri, I., Depari, N.S. 2020. *Ganoderma* Diversity from Smallholder Oil Palm Plantations in Peatlands of Kampar District, Indonesia Based on Mycelia Morphology and Somatic Incompatibility. *Biodiversitas*. 22(1).

Hasibuan, W. A. dan Hartini. 2024. Kajian Serangan Penyakit Busuk Pangkal Batang (*Ganoderma boninense*) terhadap Produktivitas Tanaman Kelapa Sawit (*Elaeis guineensis* Jacq.) di Kebun Sungai Dua Divisi I PT. Sumber Tani Agung Resources. *Prosiding Seminar Nasional Pembangunan dan Pendidikan Vokasi Pertanian V*. Politeknik Pembangunan Pertanian Manokwari. Halaman 1489- 1507.

Have, t., A., Mulder, W., Visser, J., van Kan, J.A.L. 1998. The Endopolygalacturonase Gene Bcpg1 is Required for Full Virulence of *Botrytis cinerea. Molecular Plant-Microbe Interactions*, 11(10), pp.1009–1016.

Hayati, R., Basyuni, M., Chalil, D. 2020. Genetic Diversity, Sequence and Bioinformatic Analysis of *Ganoderma boninense* Isolates. *International Journal of Agriculture and Biology,* 23(4), 763-770.

Hikmatyar, M.F., Royani, J.I., Matsunaga, K., Inoue, H., Indarto, A. 2015. Isolasi dan Amplifikasi DNA Keladi Tikus (*Thyponium flagelliform*) untuk Identifikasi Keragaman Genetik. *J. Bioteknol. Biosains Indonesia*. 2(2):42.

Hiltunen, Thorén, M., Stanojković, A., Ryberg, M., Johannesson, H. 2025. Evolution of A Bipolar Sexual Compatibility System in Marasmius. *Mycologia.* 117(1):19–33.

Ho, P-Y., Namasivayam, P., Sundram, S., Ho, C-L. 2020. Expression of Genes Encoding Manganese Peroxidase and Laccase of *Ganoderma boninense* in Response to Nitrogen Sources, Hydrogen Peroxide and Phytohormones. *Genes*. 11(11).

Ho, C.L., Tan, Y.C., Yeoh, K.A., Ghazali, A.K., Yee, W.Y., Hoh, C.C. 2016. De Novo Transcriptome Analyses of Host-Fungal Interactions in Oil Palm (*Elaeis guineensis* Jacq.). *BMC Genomics*. 19;17:66.

UNIVERSITAS
GADJAH MADA
**Identifikasi dan Analisis Ekspresi Gen Efektor Ganoderma boninense penyebab Penyakit Busuk Batang
pada Tanaman Kelapa Sawit**
Fidia Hudzaifah Akmal, Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.
**Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/**

Hofrichter, M., Ullrich, R., Pecyna, M.J., Liers, C., Lundell, T. 2010. New and Classic Families of Secreted Fungal Heme Peroxidases. *Appl. Microbiol. Biotechnol*. 87(3):871–97.

Huang, S., Zhang, X., Fernando, W.G.D. 2020. Directing Trophic Divergence in Plant-Pathogen Interactions: Antagonistic Phytohormones with NO Doubt. *Front. Plant Sci.* 11:600063.

Ismadi, Y.K.M., Mohamad, S., Harun, A. 2023. Species-specific PCR Primers for Simultaneous Detection of *Aspergillus fumigatus*, *Aspergillus terreus*, *Candida albicans* and *Candida glabrata* in Invasive Fungal Infections. *Malays J Pathol.* 45(3):397-403.

Istiqomah, F.N., Novanto, P.R., Sitanggang, M. 2024. Penurunan Kejadian dan Intensitas Penyakit Busuk Pangkal Batang Akibat Jamur *Ganoderma* pada Bibit Kelapa Sawit dengan Aplikasi Mikoriza. *Jurnal HPT*, 12(2), 105-113.

Jacobo-Velázquez, D.A., González-Agüero, M., Cisneros-Zevallos, L. 2015. Cross-talk Between Signaling Pathways: The Link Between Plant Secondary Metabolite Production and Wounding Stress Response. *Sci. Rep.* 5:8608.

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(19), 2462.

Jee, M.S., Ho, C.L., Yusof, M.T., Lau, S.Y.L., Midot, F., Lieng, L.M,. 2025. Gene expression of transcripts encoding putative secreted proteins from an oil palm fungal pathogen Ganoderma boninense. Physiological and Molecular Plant Pathology. 138:102715.

Jeon, J.R., Baldrian, P., Murugesan, K., Chang, Y.S. 2012. Laccase-catalysed Oxidations of Naturally Occurring Phenols: From In Vivo Biosynthetic Pathways to Green Synthetic Applications. *Microb. Biotechnol*. 5(3):318–32.

Jomova, K., Alomar, S.Y., Alwasel, S.H., Nepovimova, E., Kuca, K., Valko, M. 2024. Several Lines of Antioxidant Defense Against Oxidative Stress: Antioxidant Enzymes, Nanomaterials with Multiple Enzyme-Mimicking Activities, and Low-Molecular-Weight Antioxidants. *Arch. Toxicol.* 98(5):1323–67.

Kabbage, M., Yarden, O., Dickman, M.B. 2015. Pathogenic Attributes of Sclerotiniasclerotiorum : Switching From A Biotrophic to Necrotrophic Lifestyle. *Plant Sci.* 233:53–60.

Kars, I., Krooshof, G.H., Wagemakers, L., Joosten, R., Benen, J.A.E., Kan, V.J.A.L. 2005. Necrotizing Activity Of Five *Botrytis cinerea* Endopolygalacturonases Produced in *Pichia pastoris*. *Plant Journal*. 43(2): 213–225.

Karunarathna, S.C., Patabendige, N.M., Lu, W., Asad, S., Hapuarachchi, K.K. 2024. An In-Depth Study of Phytopathogenic *Ganoderma*: Pathogenicity, Advanced Detection Techniques, Control Strategies, and Sustainable Management. *J Fungi (Basel)*. 10(6).

Keerthana, J., Amrutha Lakshmi, M., Aditya, S., Ajesh, B.R. dan Manyam, P. 2023. Detection and Management of Basal Stem Rot of Oil Palm: Classical to

UNIVERSITAS
GADJAH MADA
**Identifikasi dan Analisis Ekspresi Gen Efektor Ganoderma boninense penyebab Penyakit Busuk Batang
pada Tanaman Kelapa Sawit**
Fidia Hudzaifah Akmal, Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.
**Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/**

Modern Approaches. In: Detection, Diagnosis and Management Of Soil-Borne Phytopathogens. 225–267. Singapore: *Springer Nature Singapore*.

Khairi, M.H.F., Muhammad, N.A., Bunawan, H., Murad, A.M., Ramzi, A.B. 2022. Unveiling the Core Effector Proteins of Oil Palm Pathogen Ganoderma boninense via Pan-Secretome Analysis. *J Fungi (Basel).* 29;8(8):793.

Khoo, Y.W., Chong, K.P. 2023. *Ganoderma boninense*: General Characteristics of Pathogenicity and Methods of Control. *Front. Plant Sci*. 14:1156869.

Kim, H.S., Delaney, T.P. 2002. Over-expression of TGA5, which Encodes a bZIP Transcription Factor that Interacts with NIM1/NPR1, Confers SAR-Independent Resistance in *Arabidopsis thaliana* to *Peronospora parasitica*. *Plant J.* 32(2):151–63.

Kües, U. 2015. From Two to Many: Multiple Mating Types in Basidiomycetes. *Fungal Biol*. Rev. 29(3–4):126–66.

Kulandaivelu, C.L., Maxime, M., Sheong, T.J., Christophe, K., Durant, Gasselin, T., Alwee, S.S.R.S., Frédéric, B. 2014. Identification of Laccase Genes in *Ganoderma boninense* Draft Genome Assembly. *Cirad*, 4 ,17-19.

Kusmawanto, A., Himawan, A., Kristalisasi, E. N. 2022. Antagonist Test of *Trichoderma harzianum* Against *Ganoderma boninense* Causes of Oil Palm Basal Stem Rot Disease. *Journal of Agriculture* (JoA), 1(3), 90–97.

Lekete-Lawson, E., Puije V.D.G.C., Osekre, E.A., Ackah, F.K. 2025. First Report of *Ganoderma ryvardenii* causing Basal Stem Rot (BSR) disease on oil palm (*Elaeis guineensis* Jacq.) in Ghana [version 2; peer review: 2 approved, 1 approved with reservations]. *F1000Research*,14:413.

Liu, C.Q., Hu, K.D., Li, T.T., Yang, Y., Yang, F., Li, Y., Liu, H., Chen, X.Y., Zhang, H. 2018. Correction: Polygalacturonase Gene *pgxB* in *Aspergillus nige*r is A Virulence Factor in Apple Fruit. *PLOS ONE* 13(1): e0191350.

Liu, N., Zhang, Q., Jia, H., Zhao, B., Zhu, Z., Cao, Z., Dong, J. 2022. Characterization of Laccase Gene StLAC6 and Its Involvement in The Pathogenicity and Peroxisome Function in *Setosphaeria turcica. J. Integr. Agric*. 21(7):2019–30.

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* Isolat's Aggressiveness Using Infected Oil Palm Seedlings. *J Microbiol.* 61(4):449-459.

Martínez, A.T. 2002. Molecular Biology and Structure-Function of Lignin-Degrading Heme Peroxidases. *Enzyme Microb. Technol*. 30(4):425–44.

Mattila, H., Österman-Udd, J., Mali, T. and Lundell, T. 2022. Basidiomycota Fungi and ROS: Genomic Perspective on Key Enzymes Involved in Generation and Mitigation of Reactive Oxygen Species. *Front. Fungal Biol*. 3:837605.

Ma, Y., Li, B., Yang, D., Wang, S., Yu, L., Zhan, H., Li, J. 2024. An Optimal Genomic DNA Extraction Method for Shoots of Four Dendrocalamus Species Based On Membership Function Analysis. *BioTechniques.* 76(3):94–103.

McDonald, J.G., Wong, E., White, G.P. 2000. Differentiation of *Tilletia* Species by Rep-PCR Genomic Fingerprinting. *Plant Dis* 84: 1121–1125.

UNIVERSITAS
GADJAH MADA
**Identifikasi dan Analisis Ekspresi Gen Efektor Ganoderma boninense penyebab Penyakit Busuk Batang
pada Tanaman Kelapa Sawit**
Fidia Hudzaifah Akmal, Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.
**Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/**

Mehta, Y.R., Mehta, A., Rosato, Y.B. 2002. ERIC and REP-PCR Banding Patterns and Sequence Analysis of The Internal Transcribed Spacer of rdna of *Stemphylium solani* Isolats from Cotton. *Curr Microbiol*. 44(5):323-8.

Miller, R.N.G., M. Holderness, P.D. Bridge, G.F. Chung and M.H. Zakaria. 1999. Genetic Diversity of *Ganoderma* in Oil Palm Plantings. *Plant Pathol*., 48: 595–603.

Mohan, D., Namasivayam, P., Saidi, N.B., Ho, C-L. 2022. Temporal Expression of Defense-Related Genes in *Ganoderma*-Infected Oil Palm Roots. *Trees*. 36(3):1029–38.

Nakamura, M., Iwai, H. 2019. Functions and Mechanisms: Polygalacturonases from Plant Pathogenic Fungi as Pathogenicity and Virulence Factors. *J. Gen. Plant Pathol.* 85(4):243–50.

Ng, D.W., Abeysinghe, J.K., Kamali, M. 2018. Regulating The Regulators: The Control of Transcription Factors in Plant Defense Signaling. *Int J Mol Sci*. 19(12):3737.

Niture, S.K., Kumar, A.R., Pant, A. 2006. Role of Glucose in Production and Repression of Polygalacturonase and Pectate Lyase from Phytopathogenic Fungus *Fusarium moniliforme* NCIM 1276. *World J. Microbiol. Biotechnol*. 22(9):893–99.

Nusaibah, S.A., Abdullah, S.N.A., Idris, A.S., Sariah, M., Pauzi, Z.M. 2016. Involvement of Metabolites in Early Defense Mechanism of Oil Palm (*Elaeis guineensis* Jacq.) against *Ganoderma* disease. *Plant Physiol Biochem*. 109:156–165.

Pandey, D., Rajendran, S.R.C.K., Gaur, M., Sajeesh, P.K., Kumar, A. 2016. Plant Defense Signaling and Responses Against Necrotrophic Fungal Pathogens. *J Plant Growth Regul.* 35(4):1159–1174.

PASPI Monitor. 2024. Kerugian Ekonomi Serangan *Ganoderma* Sawit dan Ancaman Masa Depan Industri Sawit Nasional. *Journal of Analysis Palm Oil Strategic Issues*. Diakses tanggal 21 Juli 2025, dari https://palmoilina.asia/jurnal-kelapa-sawit/serangan-ganoderma-sawitrugi/.

Passardi, F., Bakalovic, N., Teixeira, F.K., Margis-Pinheiro, M., Penel, C., Dunand, C. 2007. Prokaryotic Origins of The Non-Animal Peroxidase Superfamily and Organelle-Mediated Transmission to Eukaryotes. *Genomics*. 89(5):567–79.

Paterson, R.R.M. 2023. Future Climate Effects on Basal Stem Rot of Conventional and Modified Oil Palm in Indonesia and Thailand. *Forests*. 14: 1347.

Peng, S. H. T., Yap, C. K., Arshad, R., Chai, E. W., Priwiratama, H., Hidayat, F., Yanti, F., Yulizar, F., Pane, M. M., & Suprayetno, H. 2022. Efficacy of Hendersonia on the growth of seedlings of oil palm (*Elaeis guineensis* Jacq.) and *Ganoderma* disease control: A field-based study using GanoEF biofertilizer at Medan, Indonesia. *MOJ Ecology & Environmental Science*, 7(2), 24 - 29.

Perfect, S.E., Green, J.R. 2001. Infection Structures of Biotrophic and Hemibiotrophic Fungal Plant Pathogens. *Mol Plant Pathol*. 2(2):101–108.

UNIVERSITAS
GADJAH MADA
**Identifikasi dan Analisis Ekspresi Gen Efektor Ganoderma boninense penyebab Penyakit Busuk Batang
pada Tanaman Kelapa Sawit**
Fidia Hudzaifah Akmal, Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.
**Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/**

Petersen, J.F., Kadziola, A., Larsen, S. 1994. Three-Dimensional Structure of A Recombinant Peroxidase from *Coprinus cinereus* at 2.6 A resolution. *FEBS Lett*. 339(3):291– 96.

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):1841–49.

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):455–63.

Priwiratama, H., Pradana, M.G., Susanto, A., Rozziansha, T.A.P., Istiqomah, F.N. 2022. Dampak Aplikasi Konsorsium Mikoriza terhadap Pertumbuhan Vegetatif Tanaman dan Perkembangan Penyakit *Ganoderma* di Pembibitan Kelapa Sawit. *Jurnal Penelitian Kelapa Sawit*,30(3), 123-140.

Purnamasari, M.I., Prihatna, C., Gunawan, A.W., Suwanto, A. 2012. Isolasi dan Identifikasi Secara Molekuler *Ganoderma* spp. yang Berasosiasi dengan Penyakit Busuk Pangkal Batang di Kelapa Sawit. *jfi.* 8(1):9–15.

Qayyum, Z., Thomas, W.J.W., Amas, J.C., Pazos-Navarro, M., Batley, J. 2025. From Recognition to Response: Resistance-Effector Gene Interactions in the *Brassica napus* and *Leptosphaeria maculans* Patho-System. *Plants.* 14(3).

Rakib, M.R.M., Bong, C.F.J., Khairulmazmi, A., Idris, A.S. 2014. Genetic and Morphological Diversity of *Ganoderma* Species Isolate from Infected Oil Palms (*Elaeis guineensis*). *Int. J. Agric. Biol*. 16(4).

Ramzi, A.B., Che Me, M.L., Ruslan, U.S., Baharum, S.N., Nor Muhammad, N.A. 2019. Insight Into Plant Cell Wall Degradation and Pathogenesis of *Ganoderma boninense* Via Comparative Genome Analysis. *PeerJ*. Dec 18:7:e8065.

Rasmussen, S., Barah, P., Suarez-Rodriguez, M.C., Bressendorff, S., Friis, P., Costantino, P., Bones, A.M., Nielsen, H.B., Mundy, J. 2013. Transcriptome Responses to Combinations of Stresses in *Arabidopsis*. *Plant Physiol*. 161(4):1783–1794.

Rees, R.W., Flood, J., Hasan, Y., Cooper, R.M. 2007. Effects of Inoculum Potential, Shading and Soil Temperature on Root Infection of Oil Palm Seedlings by The Basal Stem Rot Pathogen *Ganoderma boninense. Plant Pathology*. 56(5):862–70.

Rossi, F.R., Krapp, A.R., Bisaro, F., Maiale, S.J., Pieckenstain, F.L., Carrillo, N. 2017. Reactive Oxygen Species Generated in Chloroplasts Contribute to Tobacco Leaf Infection by The Necrotrophic Fungus Botrytiscinerea. *Plant J.* 92(5):761–773.

Sakeh, N.M., Abdullah S.N.A., Bahari, M.N.A., Azzeme, A.M., Shaharuddin, N.A., Idris, A.S. 2021. EgJUB1 and EgERF113 Transcription Factors as Master Regulators of Defense Response in *Elaeis guineensis* Against The Hemibiotrophic *Ganoderma boninense*. *BMC Plant Study,* 21, 41.

Shapiguzov, A., Vainonen, J.P., Wrzaczek, M., Kangasjärvi, J. 2012. ROS-talk-How the Apoplast, The Chloroplast, and The Nucleus Get The Message Through. *Front. Plant Sci*. 3:292.

UNIVERSITAS
GADJAH MADA
**Identifikasi dan Analisis Ekspresi Gen Efektor Ganoderma boninense penyebab Penyakit Busuk Batang
pada Tanaman Kelapa Sawit**
Fidia Hudzaifah Akmal, Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.
**Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/**

Susilowati, A., Rachmat, H. H., Rangkuti, A. B., Elfiati, D., & Ambarwati, A. 2019. Optimizing Genomic DNA Isolation and PCR Amplification for Pasak Bumi (*Eurycoma longifolia*). *KnE Engineering*, 4(2), 30–39.

Tan, Y.C., Yeoh, K.A., Wong, M.Y., Ho, C.L. 2013. Expression Profiles of Putative Defence-related Proteins in Oil Palm (*Elaeis guineensis*) Colonized by *Ganoderma boninense*. *J. Plant Physiol*. 170(16):1455–60.

Tan, J.S., Lee, Y.P., Sulaiman, S., Camus-Kulandaivelu, L., Klopp, C., Mercière, M., Breton, F., Durand-Gasselin, T., Syed Alwee, S.S.R. 2016. The Route to The Development of Basal Stem Rot Resistance in Oil Palm (*Elaeis guineensis*) via The Discovery of Lignin Degradation Process in The Pathogen *Ganoderma boninense*. *In Proceedings of the International Symposia on Tropical and Temperate Horticulture*—ISTTH2016, Cairns, Australia, 20–25 November 2016; Volume 1205, pp. 359–370.

Thakkar, A.T., Pandya, D.C., Bhatt, S.A. 2020. Optimization of Laccase Enzyme Production by *Amesia atrobrunnea* A2: A First Report. *Biosci Biotech.Res*. 17(1):65–72.

Thurston, C.F. 1994. The Structure and Function of Fungal Laccases. *Microbiology*, 1, 19-26.

Upadhyay, P., Shrivastava, R., Agrawal, P.K. 2016. Bioprospecting and Biotechnological Applications of Fungal Laccase. *3 Biotech*. 6(1).

Versalovic, J., Lupski, J.R. 2002. Molecular Detection and Genotyping of Pathogens: More Accurate and Rapid Answers. *Trends Microbiol* 10: S15–S21.

Virdiana, I., Forster, B.P., Zakaria, L. 2024. Basal Stem Rot of Oil Palm: Disease Development in Mineral and Peat Soils. *IOP Conf. Ser.: Earth Environ. Sci*. 1308(1):012025.

Viswanath, B., Rajesh, B., Janardhan, A., Kumar, A.P., Narasimha, G. 2014. Fungal Laccases and Their Applications in Bioremediation. *Enzyme Res*. 2014:163242.

Wahab, M.A., Ahmad, K. 2024. Current Thinking on Infection and Control Strategies of Basal Stem Rot Disease of Oil Palm In Malaysia. In: Advances in Tropical Crop Protection, pp. 157–176. *Springer Nature Switzerland.*

White, T.J., Bruns, T., Lee, S.J., Taylor, J. 1990. Amplification and Direct Sequencing of Fungal Ribosomal RNA Genes for Phylogenetics. PCR Protocols: A Guide to Methods and Applications. 1; 18(1): 315–322.

Wilson, A.M., Wilken, P.M., Wingfield, M.J., Wingfield, B.D. 2021. Genetic Networks that Govern Sexual Reproduction in The Pezizomycotina. *Microbiol. Mol. Biol*. Rev. 85(4):e0002021.

Wong, W.C., Goh, Y.K., Won,g 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 Dis*. Jul;108(7):1982-1986.

Wong, W.C, Tung, H.J., Fadhilah, M.N., Midot, F., Lau, S.Y.L., Melling, L., Astari, S., Hadziabdic, Đ., Trigiano, R.N., Goh, K.J., Goh, Y.K. 2021. Genetic Diversity and Gene Flow Amongst Admixed Populations of *Ganoderma*

UNIVERSITAS
GADJAH MADA
**Identifikasi dan Analisis Ekspresi Gen Efektor Ganoderma boninense penyebab Penyakit Busuk Batang
pada Tanaman Kelapa Sawit**
Fidia Hudzaifah Akmal, Prof. Dr. Ir. Siti Subandiyah, M.Agr.Sc. ; Dr. Ir. Arif Wibowo, M.Agr.Sc.
**Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/**

*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.

Yeoh, K.A., Othman, A., Meon, S., Abdullah, F., Ho, C.L. 2012. Sequence Analysis and Gene Expression of Putative Exo and Endoglucanases from Oil Palm (*Elaeis guineensis*) During Fungal Infection. *J. Plant Physiol*. 169(15):1565–70.

Zahroni, T.R., Fahrizal, F. 2024. Mathematical Model of Basal Stem Rot (BSR) Disease Spread in Oil Palm Plants. *Poltanesa*. 25(1):147–53.

Zakaria, L. 2023. Basal Stem Rot of Oil Palm: The Pathogen, Disease Incidence, and Control Methods. *Plant Dis*. 107(3):603–15.

Zavarzina, A.G., Lisov, A.V., Leontievsky, A.A. 2018. The Role of Ligninolytic Enzymes Laccase and a Versatile Peroxidase of the White-Rot Fungus Lentinus tigrinus in Biotransformation of Soil Humic Matter: Comparative In Vivo Study. *J. Geophys. Res. Biogeosci*. 123(9):2727–42.

Zhang, S., Li, C., Si, J., Han, Z., & Chen, D. 2022. Action Mechanisms of Effectors in Plant-Pathogen Interaction. *International Journal of Molecular Sciences*, 23(12), 6758.

Zhang, W., Wang, W., Wang, J., Shen, G., Yuan, Y., Yan, L., Tang, H., Wang, W. 2021. Isolation and Characterization of A Novel Laccase for Lignin Degradation, lacz1. *Appl. Environ. Microbiol.* 87(23):e0135521.

Zhao, Z., Liu, H., Wang, C., Xu, J.R. 2014. Erratum to: Comparative Analysis of Fungal Genomes Reveals Different Plant Cell Wall Degrading Capacity in Fungi. *BMC Genomics*. 4(1):274.