Plant Pathogen Interaction pp 119–160 | Cite as

Insights into Grapevine Defence Response Against Fungal and Oomycete Diseases Towards a Sustainable Plant Breeding

Mariana Patanita , Maria do Rosário Félix, Joana A. Ribeiro, Carla M. R. Varanda, André Albuquerque, Patrick Materatski, Nicolás Garrido & Maria Doroteia Campos

Chapter | First Online: 06 January 2024

Abstract

Downy mildew, powdery mildew, grey mould, black rot, and grapevine trunk diseases are among the most important fungal or oomycete diseases affecting grapevine, with a high economic impact in all growing areas. In recent decades, extensive efforts have been made to reduce the use of agrochemicals in viticulture, turning the management of these diseases a major challenge. Given the urgent need to identify and develop new sustainable and effective protection strategies, a better understanding of plant defence mechanisms is essential to develop more tolerant plants and provide valuable insights for disease management. Although recent advances in molecular technologies have allowed the identification of several resistance genes, little is known about the complexity of the molecular mechanisms involved in grapevine-pathogen interactions. This chapter aims to bring together the most up-to-date findings on the regulation of grapevine defence mechanisms against major fungal and oomycete diseases by enumerating promising candidate genes that offer broad possibilities for inducing resistance to specific pathogens. We also focus on the use of functional genomics as a tool to study grapevine immunity to different pathogens, with particular emphasis on new emerging molecular technologies that will undoubtedly contribute to a sustainable plant breeding.

Abbreviations

BR: Black rot

CDPKs: Calcium-dependent protein kinases

CDS: Protein coding sequences

CRISPR: Clustered regularly interspaced short palindromic repeats

DEGs: Differentially expressed genes

DM: Downy mildew

dsRNA: Double-stranded RNA

ETI: Effector-triggered immunity

ETS: Effector-triggered susceptibility

GM: Grey mould

GMOs: Genetically modified organisms

GTDs: Grapevine trunk diseases

HTS: High throughput sequencing

lncRNAs: Long non-coding RNAs

LRR: Leucine-rich repeats

LRR-RLK: Leucine-rich repeat receptor-like protein kinase

MAMPs: Microbe-associated molecular patterns

MAPK: Mitogen-activated protein kinase

MAS: Marker-assisted selection

MLO: Mildew locus O

MTI: MAMPs-triggered immunity

NBS: Nucleotide-binding sites

NBTs: New breeding technologies

PAMPs: Pathogen-associated molecular patterns

PCD: Programmed cell death

PM: Powdery mildew

PR: Pathogenesis-related

PRRs: Pattern recognition receptors

PTI: PAMPs-triggered immunity

QTL: Quantitative trait loci

RGAs: Resistance gene analogues

RNAi: RNA interference

ROS: Reactive oxygen species

SBTs: Subtilases

SIGS: Spray-induced gene silencing

siRNA: Small interfering RNA

SWEET: Sugars Will Eventually be Exported Transporter

TFs: Transcription factors

TIR: Toll-interleukin receptor

TLP: Thaumatin-like protein

References

Agudelo-Romero P, Erban A, Rego C, Carbonell-Bejerano P, Nascimento T, Sousa L et al (2015) Transcriptome and metabolome reprogramming in Vitis vinifera cv. Trincadeira berries upon infection with Botrytis cinerea. J Exp Bot 66(7):1769–1785

CrossRef CAS PubMed PubMed Central Google Scholar

Aguilar CN, Cruz M, Rondríguez R, Gutierrez-Sánchez G, Ramírez-Coronel A, Augur C (2004) Catechin degradation by several fungal strains isolated from Mexican desert. J Microbiol Biotechnol 14(2):426–429

CAS Google Scholar

Ali S, Ganai BA, Kamili AN, Bhat AA, Mir ZA, Bhat JA et al (2018) Pathogenesis-related proteins and peptides as promising tools for engineering plants with multiple stress tolerance. Microbiol Res 212–213:29–37

CrossRef PubMed Google Scholar

Andersen EJ, Ali S, Byamukama E, Yen Y, Nepal MP (2018) Disease resistance mechanisms in plants. Genes (Basel) 9(7)

Google Scholar

Anderson JA, Ellsworth PC, Faria JC, Head GP, Owen MDK, Pilcher CD et al (2019) Genetically engineered crops: importance of diversified integrated pest management for agricultural sustainability. Front Bioeng Biotechnol 7:24

CrossRef PubMed PubMed Central Google Scholar

Armijo G, Espinoza C, Loyola R, Restovic F, Santibáñez C, Schlechter R et al (2016) Grapevine biotechnology: molecular approaches underlying abiotic and biotic stress responses. In: Morata A, Loira I (eds) Grape and wine biotechnology. IntechOpen, Rijeka

Google Scholar

Azevedo-Nogueira F, Rego C, Gonçalves HMR, Fortes AM, Gramaje D, Martins-Lopes P (2022) The road to molecular identification and detection of fungal grapevine trunk diseases. Front Plant Sci:13

Google Scholar

Aziz A, Perazzolli M, Gramaje D, Zyprian EM, Cantu D (2020) Editorial: recent advances on grapevine-microbe interactions: from signal perception to resistance response. Front Plant Sci 11:1164

CrossRef PubMed PubMed Central Google Scholar

Barba P, Lillis J, Luce RS, Travadon R, Osier M, Baumgartner K et al (2018) Two dominant loci determine resistance to Phomopsis cane lesions in F1 families of hybrid grapevines. Theor Appl Genet 131(5):1173–1189

CrossRef CAS PubMed PubMed Central Google Scholar

Bari R, Jones JDG (2009) Role of plant hormones in plant defence responses. Plant Mol Biol 69(4):473–488

CrossRef CAS PubMed Google Scholar

Belair M, Grau AL, Chong J, Tian X, Luo J, Guan X et al (2022) Pathogenicity factors of Botryosphaeriaceae associated with grapevine trunk diseases: new developments on their action on grapevine Defense responses. Pathogens 11(8):951

CrossRef CAS PubMed PubMed Central Google Scholar

Bennett M, Deikman J, Hendrix B, Iandolino A (2020) Barriers to efficient foliar uptake of dsRNA and molecular barriers to dsRNA activity in plant cells. Front Plant Sci:11

Google Scholar

Bent AF, Mackey D (2007) Elicitors, effectors, and R genes: the new paradigm and a lifetime supply of questions. Annu Rev Phytopathol 45:399–436

CrossRef CAS PubMed Google Scholar

Bhatia G, Upadhyay SK, Upadhyay A, Singh K (2021) Investigation of long non-coding RNAs as regulatory players of grapevine response to powdery and downy mildew infection. BMC Plant Biol 21(1):265

CrossRef CAS PubMed PubMed Central Google Scholar

Bizuneh GK (2021) The chemical diversity and biological activities of phytoalexins. Adv Tradit Med 21(1):31–43

CrossRef Google Scholar

Borges A. The grapevine defences. Walking towards the “hidden” role of dirigent proteins in Vitis vinifera secondary metabolism [PhD Thesis]: Instituto de Tecnologia Química e Biológica António Xavier, Universidade Nova de Lisboa; 2014

Google Scholar

Borrello M, Cembalo L, Vecchio R (2021) Role of information in consumers’ preferences for eco-sustainable genetic improvements in plant breeding. PLoS One 16(7):e0255130

CrossRef CAS PubMed PubMed Central Google Scholar

Boyd LA, Ridout C, O’Sullivan DM, Leach JE, Leung H (2013) Plant–pathogen interactions: disease resistance in modern agriculture. Trends Genet 29(4):233–240

CrossRef CAS PubMed Google Scholar

Breia R, Conde A, Pimentel D, Conde C, Fortes AM, Granell A et al (2020a) VvSWEET7 is a mono- and disaccharide transporter up-regulated in response to Botrytis cinerea infection in grape berries. Front. Plant Sci:10

Google Scholar

Breia R, Conde A, Conde C, Fortes AM, Granell A, Gerós H (2020b) VvERD6l13 is a grapevine sucrose transporter highly up-regulated in response to infection by Botrytis cinerea and Erysiphe necator. Plant Physiol Biochem 154:508–516

CrossRef CAS PubMed Google Scholar

Buscaill P, Rivas S (2014) Transcriptional control of plant defence responses. Curr Opin Plant Biol 20:35–46

CrossRef CAS PubMed Google Scholar

Butiuc-Keul A, Coste A (2023) Biotechnologies and strategies for grapevine improvement. Horticulturae 9(1):62

CrossRef Google Scholar

Çakir B, Kılıçkaya O (2015) Mitogen-activated protein kinase cascades in Vitis vinifera. Front Plant Sci:6

Google Scholar

Campos MD, Félix MR, Patanita M, Materatski P, Varanda C (2021a) High throughput sequencing unravels tomato-pathogen interactions towards a sustainable plant breeding. Hortic Res 8(1):171

CrossRef CAS PubMed PubMed Central Google Scholar

Campos G, Chialva C, Miras S, Lijavetzky D (2021b) New technologies and strategies for grapevine breeding through genetic transformation. Front Plant Sci:12

Google Scholar

Campos MD, Félix MR, Patanita M, Materatski P, Albuquerque A, Ribeiro JA et al (2022) Defense strategies: the role of transcription factors in tomato-pathogen interaction. Biology 11(2)

Google Scholar

Camps C, Kappel C, Lecomte P, Léon C, Gomès E, Coutos-Thévenot P et al (2010) A transcriptomic study of grapevine (Vitis vinifera cv. Cabernet-sauvignon) interaction with the vascular ascomycete fungus Eutypa lata. J Exp Bot 61(6):1719–1737

CrossRef CAS PubMed PubMed Central Google Scholar

Cao FY, Yoshioka K, Desveaux D (2011) The roles of ABA in plant-pathogen interactions. J Plant Res 124(4):489–499

CrossRef CAS PubMed Google Scholar

Capriotti L, Baraldi E, Mezzetti B, Limera C, Sabbadini S (2020) Biotechnological approaches: gene overexpression, gene silencing, and genome editing to control fungal and oomycete diseases in grapevine. Int J Mol Sci [Internet] 21(16)

Google Scholar

Cardot C, Mappa G, La Camera S, Gaillard C, Vriet C, Lecomte P et al (2019) Comparison of the molecular responses of tolerant, susceptible and highly susceptible grapevine cultivars during interaction with the pathogenic fungus Eutypa lata. Front Plant Sci 10(991)

Google Scholar

Chandran D, Rickert J, Huang Y, Steinwand MA, Marr SK, Wildermuth MC (2014) Atypical E2F transcriptional repressor DEL1 acts at the intersection of plant growth and immunity by controlling the hormone salicylic acid. Cell Host Microbe 15(4):506–513

CrossRef CAS PubMed Google Scholar

Chitarrini G, Soini E, Riccadonna S, Franceschi P, Zulini L, Masuero D et al (2017) Identification of biomarkers for defense response to Plasmopara viticola in a resistant grape variety. Front Plant Sci:8

Google Scholar

Chitarrini G, Riccadonna S, Zulini L, Vecchione A, Stefanini M, Larger S et al (2020) Two-omics data revealed commonalities and differences between Rpv12- and Rpv3-mediated resistance in grapevine. Sci Rep 10(1):12193

CrossRef CAS PubMed PubMed Central Google Scholar

Coca M, San SB (2010) AtCPK1 calcium-dependent protein kinase mediates pathogen resistance in Arabidopsis. Plant J 63(3):526–540

CrossRef CAS PubMed Google Scholar

Coutos-Thévenot P, Poinssot B, Bonomelli A, Yean HC, Bréda C, Buffard D et al (2001) In vitro tolerance to Botrytis cinerea of grapevine 41B rootstock in transgenic plants expressing the stilbene synthase Vst1 gene under the control of a pathogen-inducible PR 10 promoter. J Exp Bot 52(358):901–910

CrossRef PubMed Google Scholar

Dai L, Wang D, Xie X, Zhang C, Wang X, Xu Y et al (2016) The novel gene VpPR4-1 from Vitis pseudoreticulata increases powdery mildew resistance in transgenic Vitis vinifera L. front.

Plant Sci:7

Google Scholar

Dalla Costa L, Malnoy M, Gribaudo I (2017) Breeding next generation tree fruits: technical and legal challenges. Hortic Res 4:17067

CrossRef PubMed PubMed Central Google Scholar

Decoin M (2001) Grapevine products: news on withdrawals and restrictions. Phytoma 543:28–33

Google Scholar

Del Río JA, Gómez P, Báidez A, Fuster MD, Ortuño A, Frías V (2004) Phenolic compounds have a role in the defence mechanism protecting grapevine against the fungi involved in petri disease. Phytopathol Mediterr 43(1):87–94

Google Scholar

Delmotte F, Bourguet D, Franck P, Guillemaud T, Reboud X, Vacher C et al (2016) Combining selective pressures to enhance the durability of disease resistance genes. Front Plant Sci:7

Google Scholar

Delrot S, Grimplet J, Carbonell-Bejerano P, Schwandner A, Bert P-F, Bavaresco L et al (2020) Genetic and genomic approaches for adaptation of grapevine to climate change. In: Kole C (ed) Genomic designing of climate-smart fruit crops. Springer International Publishing, Cham, pp 157–270

CrossRef Google Scholar

Directive 2001/18/EC (2001) Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically

modified organisms and repealing council directive 90/220/EEC, pp 1–60. Available from: https://www.legislation.gov.uk/eudr/2001/18/contents

Google Scholar

Dodds PN, Rathjen JP (2010) Plant immunity: towards an integrated view of plant–pathogen interactions. Nat Rev Genet 11(8):539–548

CrossRef CAS PubMed Google Scholar

Droulia F, Charalampopoulos I (2021) Future climate change impacts on European viticulture: a review on recent scientific advances. Atmos 12(4):495

CrossRef CAS Google Scholar

Dubrovina AS, Aleynova OA, Kalachev AV, Suprun AR, Ogneva ZV, Kiselev KV (2019) Induction of transgene suppression in plants via external application of synthetic dsRNA. Int J Mol Sci 20(7):1585

CrossRef CAS PubMed PubMed Central Google Scholar

EIP-AGRI Focus Group. Diseases and pests in viticulture. Final Report 2019

Google Scholar

Fan JJ, Wang P, Xu X, Liu K, Ruan YY, Zhu YS et al (2015) Characterization of a TIR-NBS-LRR gene associated with downy mildew resistance in grape. Genet Mol Res 14(3):7964–7975

CrossRef CAS PubMed Google Scholar

Figueiredo A, Fortes AM, Ferreira S, Sebastiana M, Choi YH, Sousa L et al (2008) Transcriptional and metabolic profiling of grape (Vitis vinifera L.) leaves unravel possible innate resistance against pathogenic fungi. J Exp Bot 59(12):3371–3381

CrossRef CAS PubMed Google Scholar

Figueiredo J, Costa GJ, Maia M, Paulo OS, Malhó R, Sousa Silva M et al (2016) Revisiting Vitis vinifera Subtilase gene family: a possible role in grapevine resistance against Plasmopara viticola. Front Plant Sci 7:1783

CrossRef PubMed PubMed Central Google Scholar

Figueiredo J, Santos RB, Guerra-Guimarães L, Leclercq CC, Renaut J, Sousa L et al (2021) Revealing the secrets beneath grapevine and Plasmopara viticola early communication: a picture of host and pathogen proteomes. bioRxiv 2021:474247

Google Scholar

Fu P, Wu W, Lai G, Li R, Peng Y, Yang B et al (2020) Identifying Plasmopara viticola resistance loci in grapevine (Vitis amurensis) via genotyping-by-sequencing-based QTL mapping. Plant Physiol Biochem 154:75–84

CrossRef CAS PubMed Google Scholar

Gabler FM, Smilanick JL, Mansour M, Ramming DW, Mackey BE (2003) Correlations of morphological, anatomical, and chemical features of grape berries with resistance to Botrytis cinerea. Phytopathology 93(10):1263–1273

CrossRef PubMed Google Scholar

Gadoury D, Wilcox W, Rumbolz J, Gubler W (2019) Powdery mildew. In: Wilcox WF, Gubler WD, Uyemoto JK (eds) Compendium of grape diseases, disorders, and pests, 2nd edn. APS Press, St. Paul, pp 75–83

Google Scholar

García JA, Garrido I, Ortega A, del Moral J, Llerena JL, Espinosa F (2022) Physiological and molecular responses of Vitis vinifera cv. Tempranillo affected by esca disease. Antioxidants

[Internet] 11(9)

Google Scholar

Gassmann W, Bhattacharjee S (2012) Effector-triggered immunity Signaling: from gene-for-gene pathways to protein-protein interaction networks. Mol Plant-Microbe Interact 25(7):862–868

CrossRef CAS PubMed Google Scholar

Gebauer P, Korn M, Engelsdorf T, Sonnewald U, Koch C, Voll LM (2017) Sugar accumulation in leaves of Arabidopsis sweet11/sweet12 double mutants enhances priming of the salicylic acid-mediated defense response. Front Plant Sci:8

Google Scholar

Glazebrook J (2005) Contrasting mechanisms of Defense against biotrophic and necrotrophic pathogens. Annu Rev Phytopathol 43(1):205–227

CrossRef CAS PubMed Google Scholar

Gonçalves MFM, Nunes RB, Tilleman L, Van de Peer Y, Deforce D, Van Nieuwerburgh F et al (2019) Dual RNA sequencing of Vitis vinifera during Lasiodiplodia theobromae infection unveils host–pathogen interactions. Int J Mol Sci 20(23):6083

CrossRef PubMed PubMed Central Google Scholar

Gong P, Kang J, Sadeghnezhad E, Bao R, Ge M, Zhuge Y et al (2022) Transcriptional profiling of resistant and susceptible cultivars of grapevine (Vitis L.) reveals hypersensitive responses to Plasmopara viticola. Front Microbiol [Internet] 13:846504

CrossRef PubMed Google Scholar

Goyal N, Bhatia G, Sharma S, Garewal N, Upadhyay A, Upadhyay SK et al (2020) Genome-wide characterization revealed role of NBS-LRR genes during powdery mildew infection in Vitis vinifera. Genomics 112(1):312–322

CrossRef CAS PubMed Google Scholar

Goyal N, Bhatia G, Garewal N, Upadhyay A, Singh K (2021) Identification of defense related gene families and their response against powdery and downy mildew infections in Vitis vinifera. BMC Genomics 22(1):776

CrossRef CAS PubMed PubMed Central Google Scholar

Gramaje D, Úrbez-Torres JR, Sosnowski MR (2018) Managing grapevine trunk diseases with respect to etiology and epidemiology: current strategies and future prospects. Plant Dis 102:12–39

CrossRef PubMed Google Scholar

Guimier S, Delmotte F, Miclot AS, Fabre F, Mazet I, Couture C et al (2019) OSCAR, a national observatory to support the durable deployment of disease-resistant grapevine cultivars. International Society for Horticultural Science (ISHS), Leuven

CrossRef Google Scholar

Haile ZM, Pilati S, Sonego P, Malacarne G, Vrhovsek U, Engelen K et al (2017) Molecular analysis of the early interaction between the grapevine flower and Botrytis cinerea reveals that prompt activation of specific host pathways leads to fungus quiescence. Plant Cell Environ 40(8):1409–1428

CrossRef CAS PubMed Google Scholar

Haile ZM, Malacarne G, Pilati S, Sonego P, Moretto M, Masuero D et al (2020) Dual transcriptome and metabolic analysis of Vitis vinifera cv. Pinot Noir Berry and Botrytis cinerea during quiescence and egressed infection. Front Plant Sci 10

Google Scholar

Harms M, Holz B, Hoffmann C, Lipps HP, Silvanus W (2005) Occurrence of Guignardia bidwellii, the causal fungus of black rot on grapevine, in the vine-growing areas of Rhineland-Palatinate, Germany. Plant protection and plant health in Europe: introduction and spread of invasive species. Humboldt University, Berlin

Google Scholar

He R, Wu J, Zhang Y, Agüero CB, Li X, Liu S et al (2017) Overexpression of a thaumatin-like protein gene from Vitis amurensis improves downy mildew resistance in Vitis vinifera grapevine. Protoplasma 254(4):1579–1589

CrossRef CAS PubMed Google Scholar

Héloir M-C, Adrian M, Brulé D, Claverie J, Cordelier S, Daire X et al (2019) Recognition of elicitors in grapevine: from MAMP and DAMP perception to induced resistance. Front. Plant Sci:10

Google Scholar

Holme IB, Wendt T, Holm PB (2013) Intragenesis and cisgenesis as alternatives to transgenic crop development. Plant Biotechnol J 11(4):395–407

CrossRef CAS PubMed Google Scholar

Hu Y, Cheng Y, Yu X, Liu J, Yang L, Gao Y et al (2021) Overexpression of two CDPKs from wild Chinese grapevine enhances powdery mildew resistance in Vitis vinifera and Arabidopsis. New Phytol 230(5):2029–2046

CrossRef CAS PubMed Google Scholar

Jones JDG, Dangl JL (2006) The plant immune system. Nature 444(7117):323–329

CrossRef CAS PubMed Google Scholar

Julius BT, Leach KA, Tran TM, Mertz RA, Braun DM (2017) Sugar transporters in plants: new insights and discoveries. Plant Cell Physiol 58(9):1442–1460

CrossRef CAS PubMed Google Scholar

Kang J, Gong P, Ge M, Sadeghnezhad E, Liu Z, Zhang M et al (2021) The PLCP gene family of grapevine (Vitis vinifera L.): characterization and differential expression in response to Plasmopara viticola. BMC Plant Biol 21(1):499

Google Scholar

Kassemeyer H-H, Gadoury D, Hill G, Wilcox W (2019) Downy mildew. In: Wilcox WF, Gubler WD, Uyemoto JK (eds) Compendium of grape diseases, disorders, and pests, 2nd edn. APS Press, St. Paul, pp 46–52

Google Scholar

Kaur S, Samota MK, Choudhary M, Choudhary M, Pandey AK, Sharma A et al (2022) How do plants defend themselves against pathogens-biochemical mechanisms and genetic interventions. Physiol Mol Biol Plants 28(2):485–504

CrossRef CAS PubMed PubMed Central Google Scholar

Kenfaoui J, Radouane N, Mennani M, Tahiri A, El Ghadraoui L, Belabess Z et al (2022) A panoramic view on grapevine trunk diseases threats: case of Eutypa dieback, Botryosphaeria dieback, and esca disease. J Fungi 8(6):595

CrossRef CAS Google Scholar

Knief C (2014) Analysis of plant microbe interactions in the era of next generation sequencing technologies. Front Plant Sci 5:1–23

CrossRef Google Scholar

Li ZT, Dhekney SA, Dutt M, Gray DJ (2008) An improved protocol for agrobacterium-mediated transformation of grapevine (Vitis vinifera L.). Plant Cell Tissue Organ Cult 93(3):311–321

CrossRef Google Scholar

Limera C, Sabbadini S, Sweet JB, Mezzetti B (2017) New biotechnological tools for the genetic improvement of major Woody fruit species. Front Plant Sci:8

Google Scholar

Liu S, Zhang C, Chao N, Lu J, Zhang Y (2018) Cloning, characterization, and functional investigation of VaHAESA from Vitis amurensis inoculated with Plasmopara viticola. Int J Mol Sci 19(4):1204

CrossRef PubMed PubMed Central Google Scholar

Liu M, Ma F, Wu F, Jiang C, Wang Y (2019) Expression of stilbene synthase VqSTS6 from wild Chinese Vitis quinquangularis in grapevine enhances resveratrol production and powdery mildew resistance. Planta 250(6):1997–2007

CrossRef CAS PubMed Google Scholar

Louwaars N, Jochemsen H (2021) An ethical and societal analysis for biotechnological methods in plant breeding. Agronomy [Internet] 11(6)

Google Scholar

Maia M, Ferreira AEN, Nascimento R, Monteiro F, Traquete F, Marques AP et al (2020) Integrating metabolomics and targeted gene expression to uncover potential biomarkers of fungal/oomycetes-associated disease susceptibility in grapevine. Sci Rep 10(1):15688

CrossRef CAS PubMed PubMed Central Google Scholar

Manghwar H, Lindsey K, Zhang X, Jin S (2019) CRISPR/Cas system: recent advances and future prospects for genome editing. Trends Plant Sci 24(12):1102–1125

CrossRef CAS PubMed Google Scholar

Mangwanda R, Myburg AA, Naidoo S (2015) Transcriptome and hormone profiling reveals Eucalyptus grandis defence responses against Chrysoporthe austroafricana. BMC Genomics 16(1):319

CrossRef PubMed PubMed Central Google Scholar

Merz PR, Moser T, Höll J, Kortekamp A, Buchholz G, Zyprian E et al (2015) The transcription factor VvWRKY33 is involved in the regulation of grapevine (Vitis vinifera) defense against the oomycete pathogen Plasmopara viticola. Physiol Plant 153(3):365–380

CrossRef CAS PubMed Google Scholar

Mian G, Nassivera F, Sillani S, Iseppi L (2023) Grapevine resistant cultivars: a story review and the importance on the related wine consumption inclination. Sustainability [Internet] 15(1)

Google Scholar

Mondello V, Songy A, Battiston E, Pinto C, Coppin C, Trotel-Aziz P et al (2017) Grapevine trunk diseases: a review of fifteen years of trials for their control with chemicals and biocontrol agents. Plant Dis 102(7):1189–1217

CrossRef Google Scholar

Nascimento R, Maia M, Ferreira AEN, Silva AB, Freire AP, Cordeiro C et al (2019) Early stage metabolic events associated with the establishment of Vitis vinifera – Plasmopara viticola compatible interaction. Plant Physiol Biochem 137:1–13

CrossRef CAS PubMed Google Scholar

Nejat N, Mantri N (2017) Plant immune system: crosstalk between responses to biotic and abiotic stresses the missing link in understanding plant defence. Curr Issues Mol Biol 23:1–16

CrossRef PubMed Google Scholar

Nejat N, Mantri N (2018) Emerging roles of long non-coding RNAs in plant response to biotic and abiotic stresses. Crit Rev Biotechnol 38(1):93–105

CrossRef CAS PubMed Google Scholar

OIV (2022) State of the world vine and wine sector 2021. International Organisation of Vine and Wine. 19 p

Google Scholar

Olivares F, Loyola R, Olmedo B, MdlÁ M, Aguirre C, Vergara R et al (2021) CRISPR/Cas9 targeted editing of genes associated with fungal susceptibility in Vitis vinifera L. cv. Thompson seedless using Geminivirus-derived replicons. Front Plant Sci:12

Google Scholar

Ouadi L, Bruez E, Bastien S, Vallance J, Lecomte P, Domec J-C et al (2019) Ecophysiological impacts of Esca, a devastating grapevine trunk disease, on Vitis vinifera L. PLoS One 14(9):e0222586

CrossRef CAS PubMed PubMed Central Google Scholar

Parmar N, Singh KH, Sharma D, Singh L, Kumar P, Nanjundan J et al (2017) Genetic engineering strategies for biotic and abiotic stress tolerance and quality enhancement in horticultural crops: a comprehensive review. 3 Biotech 7(4):239

CrossRef PubMed PubMed Central Google Scholar

Patanita M, Albuquerque A, Campos MD, Materatski P, Varanda CMR, Ribeiro JA et al (2022) Metagenomic assessment unravels fungal microbiota associated to grapevine trunk diseases. Horticulturae 8(4):288

CrossRef Google Scholar

Peng Y, van Wersch R, Zhang Y (2017) Convergent and divergent Signaling in PAMP-triggered immunity and effector-triggered immunity. Mol Plant-Microbe Interact 31(4):403–409

CrossRef Google Scholar

Pereira G, Pereira J, Santos RB, Figueiredo A (2022) Uncovering the role of DNA methyltransferases in grapevine – Plasmopara viticola interaction: from genome-wide characterization to global methylation patterns. Gene 837:146693

CrossRef CAS PubMed Google Scholar

Pessina S, Lenzi L, Perazzolli M, Campa M, Dalla Costa L, Urso S et al (2016) Knockdown of MLO genes reduces susceptibility to powdery mildew in grapevine. Hortic Res 3:16016

CrossRef PubMed PubMed Central Google Scholar

Pieterse CMJ, Leon-Reyes A, Van der Ent S, Van Wees SCM (2009) Networking by small-molecule hormones in plant immunity. Nat Chem Biol 5(5):308–316

CrossRef CAS PubMed Google Scholar

Pimentel D, Amaro R, Erban A, Mauri N, Soares F, Rego C et al (2021) Transcriptional, hormonal, and metabolic changes in susceptible grape berries under powdery mildew infection. J Exp Bot 72(18):6544–6569

CrossRef CAS PubMed Google Scholar

Pirrello C, Mizzotti C, Tomazetti TC, Colombo M, Bettinelli P, Prodorutti D et al (2019) Emergent ascomycetes in viticulture: an interdisciplinary overview. Front. Plant Sci:10

Google Scholar

Pirrello C, Magon G, Palumbo F, Farinati S, Lucchin M, Barcaccia G et al (2022) Past, present and future of genetic strategies to control tolerance to the main fungal and oomycete pathogens in grapevine. J Exp Bot:erac487

Google Scholar

Poltronieri P, Marrazzo MT, Cipriani G (2020) Grapevine: resistance genes, sRNAs and immunity. In: Poltronieri P, Hong Y (eds) Applied plant biotechnology for improving resistance to biotic stress. Academic Press, pp 151–179

CrossRef Google Scholar

Qiu W, Feechan A, Dry I (2015) Current understanding of grapevine defense mechanisms against the biotrophic fungus (Erysiphe necator), the causal agent of powdery mildew disease. Horticulture. Research:2

Google Scholar

Ren C, Liu X, Zhang Z, Wang Y, Duan W, Li S et al (2016) CRISPR/Cas9-mediated efficient targeted mutagenesis in chardonnay (Vitis vinifera L.). Sci Rep 6(1):32289

CrossRef CAS PubMed PubMed Central Google Scholar

Ren C, Lin Y, Liang Z (2022) CRISPR/Cas genome editing in grapevine: recent advances, challenges and future prospects. Fruit Res 2(1):1–9

CrossRef Google Scholar

Rex F, Fechter I, Hausmann L, Töpfer R (2014) QTL mapping of black rot (Guignardia bidwellii) resistance in the grapevine rootstock 'Börner' (V. riparia Gm183 × V. cinerea Arnold). Theor Appl Genet 127(7):1667–1677

CrossRef CAS PubMed Google Scholar

Rezzonico F, Rupp O, Fahrentrapp J (2017) Pathogen recognition in compatible plant-microbe interactions. Sci Rep 7(1):6383

CrossRef PubMed PubMed Central Google Scholar

Robert-Seilaniantz A, Grant M, Jones JDG (2011) Hormone crosstalk in plant disease and defense: more than just JASMONATE-SALICYLATE antagonism. Annu Rev Phytopathol 49(1):317–343

CrossRef CAS PubMed Google Scholar

Sang H, Kim J-I (2020) Advanced strategies to control plant pathogenic fungi by host-induced gene silencing (HIGS) and spray-induced gene silencing (SIGS). Plant Biotechnol Reports 14(1):1–8

CrossRef Google Scholar

Seo E, Choi D, Choi. (2015) Functional studies of transcription factors involved in plant defenses in the genomics era. Brief Funct Genomics 14(4):260–267

CrossRef CAS PubMed Google Scholar

Singh VK, Singh AK, Singh S, Singh BD (2015) Next-generation sequencing (NGS) tools and impact in plant breeding. In: Al-Khayri JM, Jain SM, Johnson DV (eds) Advances in plant breeding strategies: breeding. Biotechnology and molecular tools. Springer International Publishing, Cham, pp 563–612

CrossRef Google Scholar

Sosa-Zuniga V, Vidal Valenzuela Á, Barba P, Espinoza Cancino C, Romero-Romero JL, Arce-Johnson P (2022) Powdery mildew resistance genes in vines: an opportunity to achieve a more sustainable viticulture. Pathogens 11(6):703

CrossRef CAS PubMed PubMed Central Google Scholar

Su H, Jiao Y-T, Wang F-F, Liu Y-E, Niu W-L, Liu G-T et al (2018) Overexpression of VpPR10.1 by an efficient transformation method enhances downy mildew resistance in V. vinifera. Plant Cell Rep 37(5):819–832

CrossRef CAS PubMed Google Scholar

Toffolatti SL, De Lorenzis G, Brilli M, Moser M, Shariati V, Tavakol E et al (2020) Novel aspects on the interaction between grapevine and Plasmopara viticola: dual-RNA-Seq analysis highlights gene expression dynamics in the pathogen and the plant during the Battle for infection. Genes [Internet] 11(3)

Google Scholar

Tomay K, Tuboly E (2023) The role of social capital and trust in the success of local wine tourism and rural development. Sociol Rural 63(1):200–222

CrossRef Google Scholar

Töpfer R, Hausmann L, Harst M, Maul E, Zyprian E, Eibach R (2011) New horizons for grapevine breeding. In: Flachowsky H, Hanke MV (eds) Fruit, vegetable and cereal science and biotechnology (Special Issue 1), vol 5. Global Science Books, UK, pp 79–100

Google Scholar

Torregrosa L, Rienth M, Luchaire N, Alcantara Novelli Dias F, Bigard A, Chatbanyong R et al (2016) The microvine, a biological model, very versatile and efficient to boost grapevine research in physiology and genetics. In: 39th OIV meeting, Bento Gonzalvez, Brazil

Google Scholar

Tsuda K, Katagiri F (2010) Comparing signaling mechanisms engaged in pattern-triggered and effector-triggered immunity. Curr Opin Plant Biol 13(4):459–465

CrossRef CAS PubMed Google Scholar

van Loon LC, Rep M, Pieterse CMJ (2006) Significance of inducible Defense-related proteins in infected plants. Annu Rev Phytopathol 44(1):135–162

CrossRef PubMed Google Scholar

Vandelle E, Ariani P, Regaiolo A, Danzi D, Lovato A, Zadra C et al (2021) The grapevine E3 ubiquitin ligase VriATL156 confers resistance against the downy mildew pathogen Plasmopara viticola. Int J Mol Sci 22(2):940

CrossRef CAS PubMed PubMed Central Google Scholar

Varanda CMR, Félix MR, Campos MD, Patanita M, Materatski P (2021) Plant viruses: from targets to tools for CRISPR. Viruses 13(1):141

CrossRef CAS PubMed PubMed Central Google Scholar

Verhagen B, Trotel-Aziz P, Jeandet P, Baillieul F, Aziz A (2011) Improved resistance against Botrytis cinerea by grapevine-associated bacteria that induce a prime oxidative burst and Phytoalexin production. Phytopathology 101(7):768–777

CrossRef CAS PubMed Google Scholar

Vezzulli S, Gramaje D, Tello J, Gambino G, Bettinelli P, Pirrello C et al (2022) Genomic designing for biotic stress resistant grapevine. In: Kole C (ed) Genomic designing for biotic stress resistant fruit crops. Springer, pp 87–255

CrossRef Google Scholar

Vidal JR, Gomez C, Cutanda MC, Shrestha BR, Bouquet A, Thomas MR et al (2010) Use of gene transfer technology for functional studies in grapevine. Aust J Grape Wine Res 16(s1):138–151

CrossRef CAS Google Scholar

Wan D-Y, Guo Y, Cheng Y, Hu Y, Xiao S, Wang Y et al (2020) CRISPR/Cas9-mediated mutagenesis of VvMLO3 results in enhanced resistance to powdery mildew in grapevine (Vitis vinifera). Hortic Res 7:116

CrossRef CAS PubMed PubMed Central Google Scholar

Wan R, Guo C, Hou X, Zhu Y, Gao M, Hu X et al (2021) Comparative transcriptomic analysis highlights contrasting levels of resistance of Vitis vinifera and Vitis amurensis to Botrytis cinerea. Hortic Res. 8:103

CrossRef CAS PubMed PubMed Central Google Scholar

Wang P, Liu C, Wang D, Liang C, Zhao K, Fan J (2013) Isolation of resistance gene analogs from grapevine resistant to downy mildew. Sci Hortic-Amsterdam 150:326–333

CrossRef CAS Google Scholar

Wang L, Xie X, Yao W, Wang J, Ma F, Wang C et al (2017a) RING-H2-type E3 gene VpRH2 from Vitis pseudoreticulata improves resistance to powdery mildew by interacting with VpGRP2A. J Exp Bot 68(7):1669–1687

CrossRef CAS PubMed Google Scholar

Wang J, Yao W, Wang L, Ma F, Tong W, Wang C et al (2017b) Overexpression of VpEIFP1, a novel F-box/Kelch-repeat protein from wild Chinese Vitis pseudoreticulata, confers higher tolerance to powdery mildew by inducing thioredoxin z proteolysis. Plant Sci 263:142–155

CrossRef CAS PubMed Google Scholar

Wang X, Tu M, Wang D, Liu J, Li Y, Li Z et al (2018) CRISPR/Cas9-mediated efficient targeted mutagenesis in grape in the first generation. Plant Biotechnol J 16(4):844–855

CrossRef CAS PubMed Google Scholar

Wang G, Liang Y-h, Zhang J-y, Cheng Z-M (2020) Cloning, molecular and functional characterization by overexpression in Arabidopsis of MAPKK genes from grapevine (Vitis vinifera). BMC Plant Biol 20(1):194

Google Scholar

Welter LJ, Tisch C, Kortekamp A, Töpfer R, Zyprian E (2017) Powdery mildew responsive genes of resistant grapevine cultivar 'Regent'. Vitis 56:181–188

CAS Google Scholar

Wilcox W, Hoffman L (2019) Black rot. In: Wilcox WF, Gubler WD, Uyemoto JK (eds) Compendium of grape diseases, disorders, and pests, 2nd edn. APS Press, St. Paul, pp 28–33

Google Scholar

Wilcox W, Mahaffee W, Gubler W (2019) Botrytis bunch rot and blight. In: Wilcox WF, Gubler WD, Uyemoto JK (eds) Compendium of grape diseases, disorders, and pests, 2nd edn. APS Press, St. Paul, pp 39–45

Google Scholar

Xu L, Liu Z-Y, Zhang K, Lu Q, Liang J, Zhang X-Y (2013) Characterization of the Pinus massoniana transcriptional response to Bursaphelenchus xylophilus infection using suppression subtractive hybridization. Int J Mol Sci [Internet] 14(6):11356–11375

CrossRef PubMed Google Scholar

Xu W, Ma F, Li R, Zhou Q, Yao W, Jiao Y et al (2019) VpSTS29/STS2 enhances fungal tolerance in grapevine through a positive feedback loop. Plant Cell Environ 42(11):2979–2998

CrossRef CAS PubMed Google Scholar

Yang S, Fresnedo-Ramírez J, Wang M, Cote L, Schweitzer P, Barba P et al (2016) A next-generation marker genotyping platform (AmpSeq) in heterozygous crops: a case study for marker-assisted selection in grapevine. Hortic Res 3:16002

CrossRef PubMed PubMed Central Google Scholar

Yanhui C, Xiaoyuan Y, Kun H, Meihua L, Jigang L, Zhaofeng G et al (2006) The MYB transcription factor superfamily of Arabidopsis: expression analysis and phylogenetic comparison with the Rice MYB family. Plant Mol Biol 60(1):107–124

CrossRef PubMed Google Scholar

Yu Y, Guo D, Li G, Yang Y, Zhang G, Li S et al (2019) The grapevine R2R3-type MYB transcription factor VdMYB1 positively regulates defense responses by activating the stilbene synthase gene 2 (VdSTS2). BMC Plant Biol 19(1):478

CrossRef PubMed PubMed Central Google Scholar

Zaidi SS-E-A, Mukhtar MS, Mansoor S (2018) Genome editing: targeting susceptibility genes for plant disease resistance. Trends Biotechnol 36(9):898–906

CrossRef CAS PubMed Google Scholar

Zhang W, Yan J, Li X, Xing Q, Chethana KWT, Zhao W (2019) Transcriptional response of grapevine to infection with the fungal pathogen Lasiodiplodia theobromae. Sci Rep 9(1):5387

CrossRef PubMed PubMed Central Google Scholar

Zhu S-Y, Yu X-C, Wang X-J, Zhao R, Li Y, Fan R-C et al (2007) Two calcium-dependent protein kinases, CPK4 and CPK11, regulate Abscisic acid signal transduction in Arabidopsis. Plant Cell 19(10):3019–3036

CrossRef CAS PubMed PubMed Central Google Scholar

Zhu H, Li C, Gao C (2020) Applications of CRISPR–Cas in agriculture and plant biotechnology. Nat Rev Mol Cell Biol 21(11):661–677

CrossRef CAS PubMed Google Scholar

Download references

Acknowledgements

This work is funded by Portuguese National Funds through FCT/MCTES under the PhD scholarships SFRH/BD/145321/2019 and 2022.13638.BD, attributed to Mariana Patanita and Joana A. Ribeiro, respectively, under the Individual Call to Scientific Employment Stimulus 2021.01553.CEECIND attributed to Patrick Materatski, and under the project UIDB/05183/2020 (MED exploratory project ID 04_2019).

Author information

Authors and Affiliations

MED - Mediterranean Institute for Agriculture, Environment and Development & CHANGE - Global Change and Sustainability Institute, Institute for Advanced Studies and Research, Universidade de Évora, Pólo da Mitra, Évora, Portugal

Mariana Patanita, Joana A. Ribeiro, Patrick Materatski & Maria Doroteia Campos

MED - Mediterranean Institute for Agriculture, Environment and Development & CHANGE - Global Change and Sustainability Institute, Departamento de Fitotecnia, Escola de Ciências e Tecnologia, Universidade de Évora, Pólo da Mitra, Évora, Portugal
Maria do Rosário Félix

ESAS, UIIPS, Instituto Politécnico de Santarém, Quinta do Galinheiro, Santarém, Portugal
Carla M. R. Varanda

MED - Mediterranean Institute for Agriculture, Environment and Development & CHANGE - Global Change and Sustainability Institute, Universidade de Évora, Pólo da Mitra, Évora, Portugal
Carla M. R. Varanda, André Albuquerque & Nicolás Garrido

Corresponding author

Correspondence to Mariana Patanita .

Editor information

Editors and Affiliations

School of Life Science, Jawaharlal Nehru University, New Delhi, India
Praveen Kumar Verma

PfBIO Ltd., Centrum, Norwich Research Park, Norwich, UK
Sonal Mishra

Department of Botany, Central University of Jammu, Jammu, India
Vikas Srivastava

Department of Biotechnology, Institute of Engineering and Technology, Lucknow, India
Shakti Mehrotra

Rights and permissions

Copyright information

About this chapter

Cite this chapter

Patanita, M. *et al.* (2023). Insights into Grapevine Defence Response Against Fungal and Oomycete Diseases Towards a Sustainable Plant Breeding. In: Verma, P.K., Mishra, S., Srivastava, V., Mehrotra, S. (eds) Plant Pathogen Interaction. Springer, Singapore. https://doi.org/10.1007/978-981-99-4890-1_5

Download citation

.RIS .ENW .BIB

DOI
https://doi.org/10.1007/978-981-99-4890-1_5

Published
06 January 2024

Publisher Name
Springer, Singapore

Print ISBN
978-981-99-4889-5

Online ISBN
978-981-99-4890-1

eBook Packages
Biomedical and Life Sciences
Biomedical and Life Sciences (R0)

Publish with us

Policies and ethics