



Universiteit
Leiden

The Netherlands

Underground alarms: volatile-mediated recruitment of beneficial soil bacteria by plants under biotic stress

Rizaludin, M.S.

Citation

Rizaludin, M. S. (2026, January 21). *Underground alarms: volatile-mediated recruitment of beneficial soil bacteria by plants under biotic stress*. NIOO-thesis. Retrieved from <https://hdl.handle.net/1887/4287295>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/4287295>

Note: To cite this publication please use the final published version (if applicable).

RR

REFERENCES

- Abuauf, H. W., Jalal, R. S., Ashy, R. A., Shami, A., Baeissa, H. M., Baz, L., Tashkandi, M. A., & Abulfaraj, A. A. (2022). Microbiome structure and response to watering in rhizosphere of *Nitrosalsola vermiculata* and surrounding bulk soil. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 50(1). <https://doi.org/10.15835/nbha50112567>
- Ahmed, M. A., Kroener, E., Holz, M., Zarebanadkouki, M., & Carminati, A. (2014). Mucilage exudation facilitates root water uptake in dry soils. *Functional Plant Biology*, 41(11), 1129–1137. <https://doi.org/10.1071/FP13330>
- Ahmed, M., Stal, L. J., & Hasnain, S. (2010). Association of non-heterocystous cyanobacteria with crop plants. *Plant and Soil*, 336(1), 363–375. <https://doi.org/10.1007/s11104-010-0488-x>
- Ahmed, M., Stal, L. J., & Hasnain, S. (2014). Biofilm formation and indole-3-acetic acid production by two rhizospheric unicellular cyanobacteria. *Journal of Microbiology and Biotechnology*, 24(8), 1015–1025. <https://doi.org/10.4014/jmb.1310.10099>
- Aksenov, A. A., Laponogov, I., Zhang, Z., Doran, S. L. F., Belluomo, I., Veselkov, D., Bittremieux, W., Nothias, L. F., Nothias-Esposito, M., Maloney, K. N., Misra, B. B., Melnik, A. V., Smirnov, A., Du, X., Jones, K. L., Dorrestein, K., Panitchpakdi, M., Ernst, M., van der Hooft, J. J. J., ... Veselkov, K. (2021). Auto-deconvolution and molecular networking of gas chromatography–mass spectrometry data. *Nature Biotechnology*, 39(2), 169–173. <https://doi.org/10.1038/s41587-020-0700-3>
- Alavi-Samani, S. M., Kachouei, M. A., & Pirbalouti, A. G. (2015). Growth, yield, chemical composition, and antioxidant activity of essential oils from two thyme species under foliar application of jasmonic acid and water deficit conditions. *Horticulture Environment and Biotechnology*, 56(4), 411–420. <https://doi.org/10.1007/s13580-015-0117-y>
- Ali, J. G., Alborn, H. T., & Stelinski, L. L. (2010). Subterranean herbivore-induced volatiles released by citrus roots upon feeding by *Diaprepes abbreviatus* recruit entomopathogenic nematodes. *Journal of Chemical Ecology*, 36(4), 361–368. <https://doi.org/10.1007/s10886-010-9773-7>
- Álvarez-Fernández, A., Díaz-Benito, P., Abadía, A., López Millán, A. F., & Abadía, J. (2014). Metal species involved in long distance metal transport in plants. *Frontiers in Plant Science*, 5(MAR), 1–20. <https://doi.org/10.3389/fpls.2014.00105>
- Ament, K., Krasikov, V., Allmann, S., Rep, M., Takken, F. L. W., & Schuurink, R. C. (2010). Methyl salicylate production in tomato affects biotic interactions. *Plant Journal*, 62(1), 124–134. <https://doi.org/10.1111/j.1365-313X.2010.04132.x>
- Ankati, S., Rani, T. S., & Podile, A. R. (2019). Changes in Root Exudates and Root Proteins in Groundnut–*Pseudomonas* sp. Interaction Contribute to Root Colonization by Bacteria and Defense Response of the Host. *Journal of Plant Growth Regulation*, 38(2), 523–538. <https://doi.org/10.1007/s00344-018-9868-x>
- Attia, S., Russel, J., Mortensen, M. S., Madsen, J. S., & Sørensen, S. J. (2022). Unexpected diversity among small-scale sample replicates of defined plant root compartments. *ISME Journal*, 16(4), 997–1003. <https://doi.org/10.1038/s41396-021-01094-7>
- Babikova, Z., Gilbert, L., Bruce, T., Dewhurst, S. Y., Pickett, J. A., & Johnson, D. (2014). Arbuscular mycorrhizal fungi and aphids interact by changing host plant quality and volatile emission. *Functional Ecology*, 28(2), 375–385. <https://doi.org/10.1111/1365-2435.12181>

- Babushok, V. I., Linstrom, P. J., & Zenkevich, I. G. (2011). Retention Indices for Frequently Reported Compounds of Plant Essential Oils. *Journal of Physical and Chemical Reference Data*, 40(4), 043101. <https://doi.org/10.1063/1.3653552>
- Badri, D. V., & Vivanco, J. M. (2009). Regulation and function of root exudates. *Plant, Cell and Environment*, 32(6), 666–681. <https://doi.org/10.1111/j.1365-3040.2009.01926.x>
- Baetz, U., & Martinoia, E. (2014). Root exudates: The hidden part of plant defense. In *Trends in Plant Science* (Vol. 19, Issue 2, pp. 90–98). <https://doi.org/10.1016/j.tplants.2013.11.006>
- Bais, H. P., Walker, T. S., Schweizer, H. P., & Vivanco, J. M. (2002). Root specific elicitation and antimicrobial activity of rosmarinic acid in hairy root cultures of *Ocimum basilicum*. *Plant Physiology and Biochemistry*, 40(11), 983–995. [https://doi.org/https://doi.org/10.1016/S0981-9428\(02\)01460-2](https://doi.org/https://doi.org/10.1016/S0981-9428(02)01460-2)
- Bakker, P. A. H. M., Pieterse, C. M. J., de Jonge, R., & Berendsen, R. L. (2018). The Soil-Borne Legacy. *Cell*, 172(6), 1178–1180. <https://doi.org/10.1016/j.cell.2018.02.024>
- Baldwin, I. T. (2010). Plant volatiles. In *Current Biology* (Vol. 20, Issue 9). Cell Press. <https://doi.org/10.1016/j.cub.2010.02.052>
- Bao, F., Zhang, T., Ding, A., Ding, A., Yang, W., Wang, J., Cheng, T., & Zhang, Q. (2020). Metabolic, Enzymatic Activity, and Transcriptomic Analysis Reveals the Mechanism Underlying the Lack of Characteristic Floral Scent in Apricot Mei Varieties. *Frontiers in Plant Science, Volume 11-2020*. <https://doi.org/10.3389/fpls.2020.574982>
- Belhassen, E., Filippi, J. J., Brévard, H., Joulain, D., & Baldovini, N. (2015). Volatile constituents of vetiver: A review. In *Flavour and Fragrance Journal* (Vol. 30, Issue 1, pp. 26–82). John Wiley and Sons Ltd. <https://doi.org/10.1002/ffj.3227>
- Berendsen, R. L., Pieterse, C. M. J., & Bakker, P. A. H. M. (2012). The rhizosphere microbiome and plant health. In *Trends in Plant Science* (Vol. 17, Issue 8, pp. 478–486). <https://doi.org/10.1016/j.tplants.2012.04.001>
- Berendsen, R. L., Vismans, G., Yu, K., Song, Y., De Jonge, R., Burgman, W. P., Burmølle, M., Herschend, J., Bakker, P. A. H. M., & Pieterse, C. M. J. (2018). Disease-induced assemblage of a plant-beneficial bacterial consortium. *ISME Journal*, 12(6), 1496–1507. <https://doi.org/10.1038/s41396-018-0093-1>
- Bicas, J. L., Fontanille, P., Pastore, G. M., & Larroche, C. (2008). Characterization of monoterpene biotransformation in two pseudomonads. *Journal of Applied Microbiology*, 105(6), 1991–2001. <https://doi.org/10.1111/j.1365-2672.2008.03923.x>
- Bizabani, C., & Dames, J. (2015). Effects of inoculating *Lachnum* and *Cadophora* isolates on the growth of *Vaccinium corymbosum*. *Microbiological Research*, 181, 68–74. <https://doi.org/10.1016/j.micres.2015.08.005>
- Boff, M. I. C., Van Tol, R. H. W. M., & Smits, P. H. (2002). Behavioural response of *Heterorhabditis megidis* towards plant roots and insect larvae. *BioControl*, 47(1), 67–83. <https://doi.org/10.1023/A:1014435627268>
- Bosch, M., Berger, S., Schaller, A., & Stintzi, A. (2014). Jasmonate-dependent induction of polyphenol oxidase activity in tomato foliage is important for defense against *Spodoptera exigua* but not against *Manduca sexta*. *BMC Plant Biology*, 14(1), 257. <https://doi.org/10.1186/s12870-014-0257-8>

- Brown, R. W., Mayser, J. P., Widdowson, C., Chadwick, D. R., & Jones, D. L. (2021). Dependence of thermal desorption method for profiling volatile organic compound (VOC) emissions from soil. *Soil Biology and Biochemistry*, 160, 108313. <https://doi.org/https://doi.org/10.1016/j.soilbio.2021.108313>
- Bulgarelli, D., Rott, M., Schlaeppli, K., Ver Loren van Themaat, E., Ahmadinejad, N., Assenza, F., Rauf, P., Huettel, B., Reinhardt, R., Schmelzer, E., Peplies, J., Gloeckner, F. O., Amann, R., Eickhorst, T., & Schulze-Lefert, P. (2012). Revealing structure and assembly cues for Arabidopsis root-inhabiting bacterial microbiota. In *Nature* (Vol. 488, Issue 7409, pp. 91–95). <https://doi.org/10.1038/nature11336>
- Callahan, B. J., McMurdie, P. J., Rosen, M. J., Han, A. W., Johnson, A. J. A., & Holmes, S. P. (2016). DADA2: High-resolution sample inference from Illumina amplicon data. *Nature Methods*, 13(7), 581–583. <https://doi.org/10.1038/nmeth.3869>
- Canarini, A., Kaiser, C., Merchant, A., Richter, A., & Wanek, W. (2019). Root exudation of primary metabolites: Mechanisms and their roles in plant responses to environmental stimuli. *Frontiers in Plant Science*, 10(February). <https://doi.org/10.3389/fpls.2019.00157>
- Canarini, A., Merchant, A., & Dijkstra, F. A. (2016). Drought effects on *Helianthus annuus* and *Glycine max* metabolites: from phloem to root exudates. *Rhizosphere*, 2, 85–97. <https://doi.org/10.1016/j.rhisph.2016.06.003>
- Castro-Severyn, J., Fortt, J., Sierralta, M., Alegria, P., Donoso, G., Choque, A., Avellaneda, A. M., Pardo-Esté, C., Saavedra, C. P., Stoll, A., & Remonsellez, F. (2024). Rhizospheric bacteria from the Atacama Desert hyper-arid core: cultured community dynamics and plant growth promotion. *Microbiology Spectrum*, 12(6). <https://doi.org/10.1128/spectrum.00056-24>
- Chalkos, D., Karamanoli, K., & Vokou, D. (2021). Monoterpene enrichments have positive impacts on soil bacterial communities and the potential of application in bioremediation. *Plants*, 10(11). <https://doi.org/10.3390/plants10112536>
- Chang, Y.-M., Jeng, W.-Y., Ko, T.-P., Yeh, Y.-J., K-M Chen, C., & H-J Wang, A. (2010). Structural study of TcaR and its complexes with multiple antibiotics from *Staphylococcus epidermidis*. *PNAS*. <https://doi.org/10.1073/pnas.0913302107/-/DCSupplemental>
- Chen, D., Ali, M. N. H. A., Kamran, M., Magsi, M. A., Mora-Poblete, F., Maldonado, C., Waris, M., Aljowaie, R. M., Zehri, M. Y., & Elshikh, M. S. (2022). The *Streptomyces chromofuscus* Strain RFS-23 Induces Systemic Resistance and Activates Plant Defense Responses against Tomato Yellow Leaf Curl Virus Infection. *Agronomy*, 12(10). <https://doi.org/10.3390/agronomy12102419>
- Chen, F., Ro, D. K., Petri, J., Gershenzon, J., Bohlmann, J., Pichersky, E., & Tholl, D. (2004). Characterization of a root-specific arabidopsis terpene synthase responsible for the formation of the volatile monoterpene 1,8-cineole. *Plant Physiology*, 135(4), 1956–1966. <https://doi.org/10.1104/pp.104.044388>
- Chen, P., Zhao, M., Tang, F., Hu, Y., Peng, X., & Shen, S. (2020). The effect of plant compartments on the *Broussonetia papyrifera*-associated fungal and bacterial communities. *Applied Microbiology and Biotechnology*, 104(8), 3627–3641. <https://doi.org/10.1007/s00253-020-10466-6>

- Chen, X., Chen, H., Yuan, J. S., Köllner, T. G., Chen, Y., Guo, Y., Zhuang, X., Chen, X., Zhang, Y. jun, Fu, J., Nebenführ, A., Guo, Z., & Chen, F. (2018). The rice terpene synthase gene *OstPS19* functions as an (S)-limonene synthase in planta, and its overexpression leads to enhanced resistance to the blast fungus *Magnaporthe oryzae*. In *Plant Biotechnology Journal* (Vol. 16, Issue 10, pp. 1778–1787). <https://doi.org/10.1111/pbi.12914>
- Chen, Y., Bonkowski, M., Shen, Y., Griffiths, B. S., Jiang, Y., Wang, X., & Sun, B. (2020). Root ethylene mediates rhizosphere microbial community reconstruction when chemically detecting cyanide produced by neighbouring plants. *Microbiome*, 8(1), 1–17. <https://doi.org/10.1186/s40168-019-0775-6>
- Chen, Y., Gozz, K., Yan, F., & Chai, Y. (2015). Acetic acid acts as a volatile signal to stimulate bacterial biofilm formation. *MBio*, 6(3). <https://doi.org/10.1128/mBio.00392-15>
- Cheng, A. X., Lou, Y. G., Mao, Y. B., Lu, S., Wang, L. J., & Chen, X. Y. (2007). Plant terpenoids: Biosynthesis and ecological functions. *Journal of Integrative Plant Biology*, 49(2), 179–186. <https://doi.org/10.1111/j.1744-7909.2007.00395.x>
- Cheng, Z., Mannion, D. T., O’Sullivan, M. G., Miao, S., Kerry, J. P., & Kilcawley, K. N. (2021). Comparison of Automated Extraction Techniques for Volatile Analysis of Whole Milk Powder. *Foods*, 10(9). <https://doi.org/10.3390/foods10092061>
- Chiriboga M., X., Campos-Herrera, R., Jaffuel, G., Röder, G., & Turlings, T. C. J. (2017). Diffusion of the maize root signal (E)- β -caryophyllene in soils of different textures and the effects on the migration of the entomopathogenic nematode *Heterorhabditis megidis*. *Rhizosphere*, 3, 53–59. <https://doi.org/10.1016/j.rhisph.2016.12.006>
- Cordovez, V., Rotoni, C., Dini-Andreote, F., Oyserman, B., Carrión, V. J., & Raaijmakers, J. M. (2021). Successive plant growth amplifies genotype-specific assembly of the tomato rhizosphere microbiome. *Science of the Total Environment*, 772. <https://doi.org/10.1016/j.scitotenv.2020.144825>
- Crespo, E., Hordijk, C. A., De Graaf, R. M., Samudrala, D., Cristescu, S. M., Harren, F. J. M., & Van Dam, N. M. (2012). On-line detection of root-induced volatiles in *Brassica nigra* plants infested with *Delia radicum* L. root fly larvae. *Phytochemistry*, 84, 68–77. <https://doi.org/10.1016/j.phytochem.2012.08.013>
- Danner, H., Brown, P., Cator, E. A., Harren, F. J. M., van Dam, N. M., & Cristescu, S. M. (2015). Aboveground and Belowground Herbivores Synergistically Induce Volatile Organic Sulfur Compound Emissions from Shoots but Not from Roots. *Journal of Chemical Ecology*, 41(7), 631–640. <https://doi.org/10.1007/s10886-015-0601-y>
- de la Fuente Cantó, C., Simonin, M., King, E., Moulin, L., Bennett, M. J., Castrillo, G., & Laplace, L. (2020). An extended root phenotype: the rhizosphere, its formation and impacts on plant fitness. *Plant Journal*, 103(3), 951–964. <https://doi.org/10.1111/tpj.14781>
- de la Porte, A., Schmidt, R., Yergeau, É., & Constant, P. (2020). A Gaseous Milieu: Extending the Boundaries of the Rhizosphere. In *Trends in Microbiology* (Vol. 28, Issue 7, pp. 536–542). Elsevier Ltd. <https://doi.org/10.1016/j.tim.2020.02.016>
- De Vries, F. T., Griffiths, R. I., Knight, C. G., Nicolitch, O., & Williams, A. (2020). Harnessing rhizosphere microbiomes for drought-resilient crop production. In *Science* (Vol. 368, Issue 6488, pp. 270–274). American Association for the Advancement of Science. <https://doi.org/10.1126/science.aaz5192>

- Del Giudice, L., Massardo, D. R., Pontieri, P., Berteà, C. M., Mombello, D., Carata, E., Tredici, S. M., Talà, A., Mucciarelli, M., Groudeva, V. I., De Stefano, M., Vigliotta, G., Maffei, M. E., & Alifano, P. (2008). The microbial community of Vetiver root and its involvement into essential oil biogenesis. *Environmental Microbiology*, 10(10), 2824–2841. <https://doi.org/10.1111/j.1462-2920.2008.01703.x>
- Delory, B. M., Delaplace, P., Fauconnier, M. L., & du Jardin, P. (2016). Root-emitted volatile organic compounds: Can they mediate belowground plant-plant interactions? In *Plant and Soil* (Vol. 402, Issues 1–2, pp. 1–26). Springer International Publishing. <https://doi.org/10.1007/s11104-016-2823-3>
- Deng, X., Wang, X., & Li, G. (2022). Nematicidal Effects of Volatile Organic Compounds from Microorganisms and Plants on Plant-Parasitic Nematodes. In *Microorganisms* (Vol. 10, Issue 6). MDPI. <https://doi.org/10.3390/microorganisms10061201>
- Desurmont, G. A., Harvey, J., Van Dam, N. M., Cristescu, S. M., Schiestl, F. P., Cozzolino, S., Anderson, P., Larsson, M. C., Kindlmann, P., Danner, H., & Turlings, T. C. J. (2014). Alien interference: Disruption of infochemical networks by invasive insect herbivores. *Plant, Cell and Environment*, 37(8), 1854–1865. <https://doi.org/10.1111/pce.12333>
- Díaz, A. S. L., Rizaludin, M. S., Zweers, H., Raaijmakers, J. M., & Garbeva, P. (2022). Exploring the Volatiles Released from Roots of Wild and Domesticated Tomato Plants under Insect Attack. *Molecules*, 27(5). <https://doi.org/10.3390/molecules27051612>
- Dicke, M., & Baldwin, I. T. (2010). The evolutionary context for herbivore-induced plant volatiles: beyond the “cry for help.” *Trends in Plant Science*, 15(3), 167–175. <https://doi.org/10.1016/j.tplants.2009.12.002>
- Diez-Simon, C., Ammerlaan, B., van den Berg, M., van Duynhoven, J., Jacobs, D., Mumm, R., & Hall, R. D. (2020). Comparison of volatile trapping techniques for the comprehensive analysis of food flavourings by Gas Chromatography-Mass Spectrometry. *Journal of Chromatography A*, 1624, 461191. <https://doi.org/https://doi.org/10.1016/j.chroma.2020.461191>
- Dissanayaka, D. M. S. B., Wickramasinghe, W. M. K. R., Marambe, B., & Wasaki, J. (2017). Phosphorus-mobilization strategy based on carboxylate exudation in lupins (lupinus, fabaceae): A mechanism facilitating the growth and phosphorus acquisition of neighbouring plants under phosphorus-limited conditions. *Experimental Agriculture*, 53(2), 308–319. <https://doi.org/10.1017/S0014479716000351>
- Du, X., Smirnov, A., Pluskal, T., Jia, W., & Sumner, S. (2020). Metabolomics Data Preprocessing Using ADAP and MZmine 2. In S. Li (Ed.), *Computational Methods and Data Analysis for Metabolomics* (pp. 25–48). Springer US. https://doi.org/10.1007/978-1-0716-0239-3_3
- Dudareva, N., Negre, F., Nagegowda, D. A., & Orlova, I. (2006). Plant volatiles: Recent advances and future perspectives. *Critical Reviews in Plant Sciences*, 25(5), 417–440. <https://doi.org/10.1080/07352680600899973>
- Dudareva, N., Pichersky, E., & Gershenzon, J. (2004). Biochemistry of plant volatiles. *Plant Physiology*, 135(4), 1893–1902. <https://doi.org/10.1104/pp.104.049981>

- Edwards, J., Johnson, C., Santos-Medellín, C., Lurie, E., Podishetty, N. K., Bhatnagar, S., Eisen, J. A., Sundaresan, V., & Jeffery, L. D. (2015). Structure, variation, and assembly of the root-associated microbiomes of rice. *Proceedings of the National Academy of Sciences of the United States of America*, 112(8), E911–E920. <https://doi.org/10.1073/pnas.1414592112>
- Ehlers, B. K., Berg, M. P., Staudt, M., Holmstrup, M., Glasius, M., Ellers, J., Tomiolo, S., Madsen, R. B., Slotsbo, S., & Penuelas, J. (2020). Plant Secondary Compounds in Soil and Their Role in Belowground Species Interactions. *Trends in Ecology and Evolution*, 35(8), 716–730. <https://doi.org/10.1016/j.tree.2020.04.001>
- Eilers, E. J., Pauls, G., Rillig, M. C., Hansson, B. S., Hilker, M., & Reinecke, A. (2015). Novel Set-Up for Low-Disturbance Sampling of Volatile and Non-volatile Compounds from Plant Roots. *Journal of Chemical Ecology*, 41(3), 253–266. <https://doi.org/10.1007/s10886-015-0559-9>
- Erb, M., Robert, C. A. M., Marti, G., Lu, J., Doyen, G. R., Villard, N., Barrière, Y., French, B. W., Wolfender, J. L., Turlings, T. C. J., & Gershenzon, J. (2015). A physiological and behavioral mechanism for leaf herbivore-induced systemic root resistance. *Plant Physiology*, 169(4), 2884–2894. <https://doi.org/10.1104/pp.15.00759>
- Feng, H., Zhang, N., Du, W., Zhang, H., Liu, Y., Fu, R., Shao, J., Zhang, G., Shen, Q., & Zhang, R. (2018). Identification of chemotaxis compounds in root exudates and their sensing chemoreceptors in plant-growth-promoting rhizobacteria *Bacillus amyloliquefaciens* SQR9. *Molecular Plant-Microbe Interactions*, 31(10), 995–1005. <https://doi.org/10.1094/MPMI-01-18-0003-R>
- Feng, Z., Liang, Q., Yao, Q., Bai, Y., & Zhu, H. (2024). The role of the rhizobiome recruited by root exudates in plant disease resistance: current status and future directions. In *Environmental Microbiome* (Vol. 19, Issue 1). BioMed Central Ltd. <https://doi.org/10.1186/s40793-024-00638-6>
- Fernández, E., Trillas, M. I., & Segarra, G. (2017). Increased rhizosphere populations of *Trichoderma asperellum* strain T34 caused by secretion pattern of root exudates in tomato plants inoculated with *Botrytis cinerea*. *Plant Pathology*, 66(7), 1110–1116. <https://doi.org/10.1111/ppa.12668>
- Fernández, M., Matilla, M. A., Ortega, Á., & Krell, T. (2017). Metabolic value chemoattractants are preferentially recognized at broad ligand range chemoreceptor of *Pseudomonas putida* KT2440. *Frontiers in Microbiology*, 8(MAY). <https://doi.org/10.3389/fmicb.2017.00990>
- Ferrero, V., Baeten, L., Blanco-Sánchez, L., Planelló, R., Díaz-Pendón, J. A., Rodríguez-Echeverría, S., Haegeman, A., & de la Peña, E. (2020). Complex patterns in tolerance and resistance to pests and diseases underpin the domestication of tomato. *New Phytologist*, 226(1), 254–266. <https://doi.org/10.1111/nph.16353>
- Fitzpatrick, C. R., Copeland, J., Wang, P. W., Guttman, D. S., Kotanen, P. M., & Johnson, M. T. J. (2018). Assembly and ecological function of the root microbiome across angiosperm plant species. *Proceedings of the National Academy of Sciences of the United States of America*, 115(6), E1157–E1165. <https://doi.org/10.1073/pnas.1717617115>

- Flemming, H. C., Wingender, J., Szewzyk, U., Steinberg, P., Rice, S. A., & Kjelleberg, S. (2016). Biofilms: An emergent form of bacterial life. In *Nature Reviews Microbiology* (Vol. 14, Issue 9, pp. 563–575). Nature Publishing Group. <https://doi.org/10.1038/nrmicro.2016.94>
- Forouhar, F., Yang, Y., Kumar, D., Chen, Y., Fridman, E., Park, S. W., Chiang, Y., Acton, T. B., Montelione, G. T., Pichersky, E., Klessig, D. F., & Tong, L. (2005). Structural and biochemical studies identify tobacco SABP2 as a methyl salicylate esterase and implicate it in plant innate immunity. *Proceedings of the National Academy of Sciences*, 102(5), 1773–1778. <https://doi.org/10.1073/pnas.0409227102>
- Foss, S., Heyen, U., & Harder, J. (1998). *Alcaligenes defragrans* sp. nov., Description of Four Strains Isolated on Alkenoic Monoterpenes ((+)-menthene, α -pinene, 2-carene, and α -phellandrene) and Nitrate. *Systematic and Applied Microbiology*, 21(2), 237–244. [https://doi.org/10.1016/S0723-2020\(98\)80028-3](https://doi.org/10.1016/S0723-2020(98)80028-3)
- French, E., Tran, T., & Iyer-Pascuzzi, A. S. (2020). Tomato genotype modulates selection and responses to root microbiota. *Phytobiomes Journal*, 4(4), 314–326. <https://doi.org/10.1094/PBIOMES-02-20-0020-R>
- Friman, J., Karssemeijer, P. N., Haller, J., de Kreek, K., van Loon, J. J. A., & Dicke, M. (2021). Shoot and root insect herbivory change the plant rhizosphere microbiome and affects cabbage–insect interactions through plant–soil feedback. *New Phytologist*, 232(6), 2475–2490. <https://doi.org/10.1111/nph.17746>
- Gargallo-Garriga, A., Preece, C., Sardans, J., Oravec, M., Urban, O., & Peñuelas, J. (2018). Root exudate metabolomes change under drought and show limited capacity for recovery. *Scientific Reports*, 8(1), 1–15. <https://doi.org/10.1038/s41598-018-30150-0>
- Gfeller, V., Huber, M., Förster, C., Huang, W., Köllner, T. G., & Erb, M. (2019). Root volatiles in plant–plant interactions I: High root sesquiterpene release is associated with increased germination and growth of plant neighbours. *Plant Cell and Environment*, 42(6), 1950–1963. <https://doi.org/10.1111/pce.13532>
- Gulati, S., Ballhausen, M. B., Kulkarni, P., Grosch, R., & Garbeva, P. (2020). A non-invasive soil-based setup to study tomato root volatiles released by healthy and infected roots. *Scientific Reports*, 10(1), 1–11. <https://doi.org/10.1038/s41598-020-69468-z>
- Gupta, S., Rupasinghe, T., Callahan, D. L., Natera, S. H. A., Smith, P. M. C., Hill, C. B., Roessner, U., & Boughton, B. A. (2019). Spatio-Temporal Metabolite and Elemental Profiling of Salt Stressed Barley Seeds During Initial Stages of Germination by MALDI-MSI and μ -XRF Spectrometry. *Frontiers in Plant Science*, 10(September), 1–17. <https://doi.org/10.3389/fpls.2019.01139>
- Halo, B. A., Khan, A. L., Waqas, M., Al-Harrasi, A., Hussain, J., Ali, L., Adnan, M., & Lee, I. J. (2015). Endophytic bacteria (*Sphingomonas* sp. LK11) and gibberellin can improve *solanum lycopersicum* growth and oxidative stress under salinity. *Journal of Plant Interactions*, 10(1), 117–125. <https://doi.org/10.1080/17429145.2015.1033659>
- Hamilton-Kemp, T. R., McCracken, C. T., Loughrin, J. H., Andersen, R. A., & Hildebrand, D. F. (1992). Effects of some natural volatile compounds on the pathogenic fungi *Alternaria alternata* and *Botrytis cinerea*. *Journal of Chemical Ecology*, 18(7), 1083–1091. <https://doi.org/10.1007/BF00980064>

- Haney, C. H., Wiesmann, C. L., Shapiro, L. R., Melnyk, R. A., O'Sullivan, L. R., Khorasani, S., Xiao, L., Han, J., Bush, J., Carrillo, J., Pierce, N. E., & Ausubel, F. M. (2018). Rhizosphere-associated *Pseudomonas* induce systemic resistance to herbivores at the cost of susceptibility to bacterial pathogens. *Molecular Ecology*, 27(8), 1833–1847. <https://doi.org/10.1111/mec.14400>
- Hanzel, J., Harms, H., & Wick, L. Y. (2010). Bacterial chemotaxis along vapor-phase gradients of naphthalene. *Environmental Science and Technology*, 44(24), 9304–9310. <https://doi.org/10.1021/es100776h>
- Hartmann, T. (2004). Plant-derived secondary metabolites as defensive chemicals in herbivorous insects: A case study in chemical ecology. *Planta*, 219(1), 1–4. <https://doi.org/10.1007/s00425-004-1249-y>
- Henry, A., Doucette, W., Norton, J., & Bugbee, B. (2007). Changes in Crested Wheatgrass Root Exudation Caused by Flood, Drought, and Nutrient Stress. *Journal of Environmental Quality*, 36(3), 904–912. <https://doi.org/10.2134/jeq2006.0425sc>
- Hermes, C. H., Hennessy, R. C., Bak, F., Dresbøll, D. B., & Nicolaisen, M. H. (2022). Back to our roots: exploring the role of root morphology as a mediator of beneficial plant–microbe interactions. In *Environmental Microbiology* (Vol. 24, Issue 8, pp. 3264–3272). John Wiley and Sons Inc. <https://doi.org/10.1111/1462-2920.15926>
- Hernández-Aparicio, F., Lisón, P., Rodrigo, I., Bellés, J. M., & López-Gresa, M. P. (2021). Signaling in the Tomato Immunity against *Fusarium oxysporum*. *Molecules*, 26(7). <https://doi.org/10.3390/molecules26071818>
- Herrou, J., Bompard, C., Wintjens, R., Dupré, E., Willery, E., Villeret, V., Locht, C., Antoine, R., & Jacob-Dubuisson, F. (2010). Periplasmic domain of the sensor-kinase BvgS reveals a new paradigm for the Venus flytrap mechanism. *Proceedings of the National Academy of Sciences of the United States of America*, 107(40), 17351–17355. <https://doi.org/10.1073/pnas.1006267107>
- Hiltbold, I., Erb, M., Robert, C. A. M., & Turlings, T. C. J. (2011). Systemic root signalling in a belowground, volatile-mediated tritrophic interaction. *Plant, Cell and Environment*, 34(8), 1267–1275. <https://doi.org/10.1111/j.1365-3040.2011.02327.x>
- Hiltbold, I., & Turlings, T. C. J. (2008). Belowground chemical signaling in maize: When simplicity rhymes with efficiency. *Journal of Chemical Ecology*, 34(5), 628–635. <https://doi.org/10.1007/s10886-008-9467-6>
- Holopainen, J. K., & Gershenzon, J. (2010). Multiple stress factors and the emission of plant VOCs. *Trends in Plant Science*, 15(3), 176–184. <https://doi.org/10.1016/j.tplants.2010.01.006>
- Hopkins, R. J., Van Dam, N. M., & Van Loon, J. J. A. (2009). Role of glucosinolates in insect-plant relationships and multitrophic interactions. *Annual Review of Entomology*, 54, 57–83. <https://doi.org/10.1146/annurev.ento.54.110807.090623>
- Hou, S., Wolinska, K. W., & Hacquard, S. (2021). Microbiota-root-shoot-environment axis and stress tolerance in plants. In *Current Opinion in Plant Biology* (Vol. 62). Elsevier Ltd. <https://doi.org/10.1016/j.pbi.2021.102028>
- Hu, L., Robert, C. A. M., Cadot, S., Zhang, X., Ye, M., Li, B., Manzo, D., Chervet, N., Steinger, T., Van Der Heijden, M. G. A., Schlaeppli, K., & Erb, M. (2018). Root exudate metabolites drive plant-soil feedbacks on growth and defense by shaping the rhizosphere microbiota. *Nature Communications*, 9(1), 1–13. <https://doi.org/10.1038/s41467-018-05122-7>

- Hu, L., Zhang, K., Xu, Y., Zheng, X., Waterman, J. M., Ouyang, X., Wu, Z., Shen, Z., He, Y., Ma, B., Robert, C. A. M., Raaijmakers, J. M., Ye, M., Erb, M., & Xu, J. (2025). Herbivory-induced green leaf volatiles increase plant performance through jasmonate-dependent plant–soil feedbacks. *Nature Plants*, 11(5), 1001–1017. <https://doi.org/10.1038/s41477-025-01987-x>
- Huang, A. C., Jiang, T., Liu, Y. X., Bai, Y. C., Reed, J., Qu, B., Goossens, A., Nützmann, H. W., Bai, Y., & Osbourn, A. (2019). A specialized metabolic network selectively modulates *Arabidopsis* root microbiota. *Science*, 364(6440). <https://doi.org/10.1126/science.aau6389>
- Huang, X. F., Chaparro, J. M., Reardon, K. F., Zhang, R., Shen, Q., & Vivanco, J. M. (2014). Rhizosphere interactions: Root exudates, microbes, and microbial communities1. In *Botany* (Vol. 92, Issue 4, pp. 267–275). National Research Council of Canada. <https://doi.org/10.1139/cjb-2013-0225>
- Jansen, R. M. C., Miebach, M., Kleist, E., Van Henten, E. J., & Wildt, J. (2009). Release of lipoxygenase products and monoterpenes by tomato plants as an indicator of *Botrytis cinerea*-induced stress. *Plant Biology*, 11(6), 859–868. <https://doi.org/10.1111/j.1438-8677.2008.00183.x>
- Jin, C. W., Li, G. X., Yu, X. H., & Zheng, S. J. (2010). Plant Fe status affects the composition of siderophore-secreting microbes in the rhizosphere. *Annals of Botany*, 105(5), 835–841. <https://doi.org/10.1093/aob/mcq071>
- Jin, J., Zhao, M., Gao, T., Jing, T., Zhang, N., Wang, J., Zhang, X., Huang, J., Schwab, W., & Song, C. (2021). Amplification of early drought responses caused by volatile cues emitted from neighboring tea plants. *Horticulture Research*, 8, 243. <https://doi.org/10.1038/s41438-021-00704-x>
- Johnson, S. N., & Nielsen, U. N. (2012). Foraging in the Dark - Chemically Mediated Host Plant Location by Belowground Insect Herbivores. *Journal of Chemical Ecology*, 38(6), 604–614. <https://doi.org/10.1007/s10886-012-0106-x>
- Jousset, A., Rochat, L., Lanoue, A., Bonkowski, M., Keel, C., & Scheu, S. (2011). Plants respond to pathogen infection by enhancing the antifungal gene expression of root-associated bacteria. *Molecular Plant-Microbe Interactions*, 24(3), 352–358. <https://doi.org/10.1094/MPMI-09-10-0208>
- Kashyap, B., & Kumar, R. (2021). Sensing methodologies in agriculture for monitoring biotic stress in plants due to pathogens and pests. *Inventions*, 6(2). <https://doi.org/10.3390/INVENTIONS6020029>
- Kazmi, R. H., Willems, L. A. J., Joosen, R. V. L., Khan, N., Ligterink, W., & Hilhorst, H. W. M. (2017). Metabolomic analysis of tomato seed germination. *Metabolomics*, 13(12). <https://doi.org/10.1007/s11306-017-1284-x>
- Ketehouli, T., Pasche, J., Buttrós, V. H., Goss, E. M., & Martins, S. J. (2024). The underground world of plant disease: Rhizosphere dysbiosis reduces above-ground plant resistance to bacterial leaf spot and alters plant transcriptome. *Environmental Microbiology*, 26(7). <https://doi.org/10.1111/1462-2920.16676>
- Khan, A. L., Waqas, M., Kang, S. M., Al-Harrasi, A., Hussain, J., Al-Rawahi, A., Al-Khiziri, S., Ullah, I., Ali, L., Jung, H. Y., & Lee, I. J. (2014). Bacterial endophyte *Sphingomonas* sp. LK11 produces gibberellins and IAA and promotes tomato plant growth. *Journal of Microbiology*, 52(8), 689–695. <https://doi.org/10.1007/s12275-014-4002-7>

- Khan, N., Kazmi, R. H., Willems, L. A. J., van Heusden, A. W., Ligterink, W., & Hilhorst, H. W. M. (2012). Exploring the Natural Variation for Seedling Traits and Their Link with Seed Dimensions in Tomato. *PLoS ONE*, 7(8). <https://doi.org/10.1371/journal.pone.0043991>
- Kissen, R., Rossiter, J. T., & Bones, A. M. (2009). The “mustard oil bomb”: Not so easy to assemble?! Localization, expression and distribution of the components of the myrosinase enzyme system. *Phytochemistry Reviews*, 8(1), 69–86. <https://doi.org/10.1007/s11101-008-9109-1>
- Kleinheinz, G. T., Bagley, S. T., St John, W. P., Rughani, J. R., & McGinnis, G. D. (n.d.). *Characterization of Alpha-Pinene-Degrading Microorganisms and Application to a Bench-Scale Biofiltration System for VOC Degradation*.
- Knights, H. E., Jorin, B., Haskett, T. L., & Poole, P. S. (2021). Deciphering bacterial mechanisms of root colonization. In *Environmental Microbiology Reports* (Vol. 13, Issue 4, pp. 428–444). John Wiley and Sons Inc. <https://doi.org/10.1111/1758-2229.12934>
- Kobayashi, K. (2015). Plant methyl salicylate induces defense responses in the rhizobacterium *Bacillus subtilis*. *Environmental Microbiology*, 17(4), 1365–1376. <https://doi.org/10.1111/1462-2920.12613>
- Köllner, T. G., Held, M., Lenk, C., Hiltbold, I., Turlings, T. C. J., Gershenzon, J., & Degenhardt, J. (2008). A Maize (E)- β -Caryophyllene Synthase Implicated in Indirect Defense Responses against Herbivores Is Not Expressed in Most American Maize Varieties. *The Plant Cell*, 20(2), 482–494. <https://doi.org/10.1105/tpc.107.051672>
- Kong, H. G., Song, G. C., Sim, H. J., & Ryu, C. M. (2021). Achieving similar root microbiota composition in neighbouring plants through airborne signalling. *ISME Journal*, 15(2), 397–408. <https://doi.org/10.1038/s41396-020-00759-z>
- Koprivova, A., & Kopriva, S. (2022). Plant secondary metabolites altering root microbiome composition and function. In *Current Opinion in Plant Biology* (Vol. 67). Elsevier Ltd. <https://doi.org/10.1016/j.pbi.2022.102227>
- Kuchikata, H., Sano, M., Fujiwara, F., Murashima, K., Kumaishi, K., Narukawa, M., Nose, Y., Kobayashi, M., Hamamoto, S., Kobayashi, N. I., Sugiyama, A., Nihei, N., Ichihashi, Y., & Kusano, M. (2024). Soil volatilomics uncovers tight linkage between soybean presence and soil omics profiles in agricultural fields. *Scientific Reports*, 14(1). <https://doi.org/10.1038/s41598-024-70873-x>
- Kulkarni, O. S., Mazumder, M., Kini, S., Hill, E. D., Aow, J. S. B., Phua, S. M. L., Elejalde, U., Kjelleberg, S., & Swarup, S. (2024). Volatile methyl jasmonate from roots triggers host-beneficial soil microbiome biofilms. *Nature Chemical Biology*, 20(4), 473–483. <https://doi.org/10.1038/s41589-023-01462-8>
- Kulkarni, P., Wilschut, R. A., Verhoeven, K. J. F., van der Putten, W. H., & Garbeva, P. (2018). LAESI mass spectrometry imaging as a tool to differentiate the root metabolome of native and range-expanding plant species. *Planta*, 248(6), 1515–1523. <https://doi.org/10.1007/s00425-018-2989-4>
- Kumari, N., Menghani, E., & Mithal, R. (2020). GCMS analysis & assessment of antimicrobial potential of rhizospheric Actinomycetes of AIA3 isolate. In *Indian Journal of Traditional Knowledge* (Vol. 19, Issue 1).

- Kwak, M. J., Kong, H. G., Choi, K., Kwon, S. K., Song, J. Y., Lee, J., Lee, P. A., Choi, S. Y., Seo, M., Lee, H. J., Jung, E. J., Park, H., Roy, N., Kim, H., Lee, M. M., Rubin, E. M., Lee, S. W., & Kim, J. F. (2018). Rhizosphere microbiome structure alters to enable wilt resistance in tomato. *Nature Biotechnology*, 36(11), 1100–1116. <https://doi.org/10.1038/nbt.4232>
- Lackus, N. D., Schmidt, A., Gershenzon, J., & Köllner, T. G. (2021). A peroxisomal β -oxidative pathway contributes to the formation of C6–C1 aromatic volatiles in poplar. *Plant Physiology*, 186(2), 891–909. <https://doi.org/10.1093/plphys/kiab111>
- Lakshmanan, V., Castaneda, R., Rudrappa, T., & Bais, H. P. (2013). Root transcriptome analysis of *Arabidopsis thaliana* exposed to beneficial *Bacillus subtilis* FB17 rhizobacteria revealed genes for bacterial recruitment and plant defense independent of malate efflux. *Planta*, 238(4), 657–668. <https://doi.org/10.1007/s00425-013-1920-2>
- Lanoue, A., Burlat, V., Henkes, G. J., Koch, I., Schurr, U., & Röse, U. S. R. (2010). De novo biosynthesis of defense root exudates in response to *Fusarium* attack in barley. *New Phytologist*, 185(2), 577–588. <https://doi.org/10.1111/j.1469-8137.2009.03066.x>
- Lebeis, S. L., Paredes, S. H., Lundberg, D. S., Breakfield, N., Gehring, J., McDonald, M., Malfatti, S., Glavina del Rio, T., Jones, C. D., Tringe, S. G., & Dangl, J. L. (2015). Salicylic acid modulates colonization of the root microbiome by specific bacterial taxa. *Science*, 349(6250), 860–864. <https://doi.org/10.1126/science.aaa8764>
- Lee Díaz, A. S., Minchev, Z., Raaijmakers, J. M., Pozo, M. J., & Garbeva, P. (2024). Impact of bacterial and fungal inoculants on the resident rhizosphere microbiome and the volatilome of tomato plants under leaf herbivory stress. *FEMS Microbiology Ecology*, 100(2). <https://doi.org/10.1093/femsec/fiad160>
- Lee, S. A., Kim, Y., Kim, J. M., Chu, B., Joa, J. H., Sang, M. K., Song, J., & Weon, H. Y. (2019). A preliminary examination of bacterial, archaeal, and fungal communities inhabiting different rhizocompartments of tomato plants under real-world environments. *Scientific Reports*, 9(1). <https://doi.org/10.1038/s41598-019-45660-8>
- Létoffé, S., Audrain, B., Bernier, S. P., Delepierre, M., & Ghigo, J. M. (2014). Aerial exposure to the bacterial volatile compound trimethylamine modifies antibiotic resistance of physically separated bacteria by raising culture medium pH. *MBio*, 5(1). <https://doi.org/10.1128/mBio.00944-13>
- Li, Y., He, X., Yuan, H., & Lv, G. (2022). Differed Growth Stage Dynamics of Root-Associated Bacterial and Fungal Community Structure Associated with Halophytic Plant *Lycium ruthenicum*. *Microorganisms*, 10(8). <https://doi.org/10.3390/microorganisms10081644>
- Liang, C., Piñeros, M. A., Tian, J., Yao, Z., Sun, L., Liu, J., Shaff, J., Coluccio, A., Kochian, L. V., & Liao, H. (2013). Low pH, aluminum, and phosphorus coordinately regulate malate exudation through GmALMT1 to improve soybean adaptation to acid soils. *Plant Physiology*, 161(3), 1347–1361. <https://doi.org/10.1104/pp.112.208934>
- Lin, C., Owen, S. M., & Peñuelas, J. (2007). Volatile organic compounds in the roots and rhizosphere of *Pinus* spp. *Soil Biology and Biochemistry*, 39(4), 951–960. <https://doi.org/10.1016/j.soilbio.2006.11.007>

- Lin, Y., Qasim, M., Hussain, M., Akutse, K. S., Avery, P. B., Dash, C. K., & Wang, L. (2017). The Herbivore-Induced Plant Volatiles Methyl Salicylate and Menthol Positively affect Growth and Pathogenicity of Entomopathogenic Fungi. *Scientific Reports*, 7. <https://doi.org/10.1038/srep40494>
- Liu, H., & Brettell, L. E. (2019). Plant Defense by VOC-Induced Microbial Priming. *Trends in Plant Science*, 24(3), 187–189. <https://doi.org/10.1016/j.tplants.2019.01.008>
- Liu, H., Li, J., Carvalhais, L. C., Percy, C. D., Prakash Verma, J., Schenk, P. M., & Singh, B. K. (2021). Evidence for the plant recruitment of beneficial microbes to suppress soil-borne pathogens. *New Phytologist*, 229(5), 2873–2885. <https://doi.org/10.1111/nph.17057>
- Liu, Y., Chen, L., Wu, G., Feng, H., Zhang, G., Shen, Q., & Zhang, R. (2017). Identification of root-secreted compounds involved in the communication between cucumber, the beneficial bacillus amyloliquefaciens, and the soil-borne pathogen fusarium oxysporum. *Molecular Plant-Microbe Interactions*, 30(1), 53–62. <https://doi.org/10.1094/MPMI-07-16-0131-R>
- Liu, Y., Xu, Z., Chen, L., Xun, W., Shu, X., Chen, Y., Sun, X., Wang, Z., Ren, Y., Shen, Q., & Zhang, R. (2024). Root colonization by beneficial rhizobacteria. In *FEMS Microbiology Reviews* (Vol. 48, Issue 1). Oxford University Press. <https://doi.org/10.1093/femsre/fuad066>
- Lombardi, N., Vitale, S., Turr À, D., Reverberi, M., Fanelli, C., Vinale, F., Marra, R., Ruocco, M., Pascale, A., D'Errico, G., Woo, S. L., & Lorito, M. (2018). Root exudates of stressed plants stimulate and attract trichoderma soil fungi. *Molecular Plant-Microbe Interactions*, 31(10), 982–994. <https://doi.org/10.1094/MPMI-12-17-0310-R>
- López-Ráez, J. A., Pozo, M. J., & García-Garrido, J. M. (2011). Strigolactones: A cry for help in the rhizosphere. In *Botany* (Vol. 89, Issue 8, pp. 513–522). NRC Research Press. <https://doi.org/10.1139/b11-046>
- Lozano-Andrade, C. N., Nogueira, C. G., Henriksen, N. N. S. E., Wibowo, M., Jarmusch, S. A., & Kovács, Á. T. (2023). Establishment of a transparent soil system to study *Bacillus subtilis* chemical ecology. *ISME Communications*, 3(1). <https://doi.org/10.1038/s43705-023-00318-5>
- Lucas-Barbosa, D., Sun, P., Hakman, A., van Beek, T. A., van Loon, J. J. A., & Dicke, M. (2016). Visual and odour cues: Plant responses to pollination and herbivory affect the behaviour of flower visitors. *Functional Ecology*, 30(3), 431–441. <https://doi.org/10.1111/1365-2435.12509>
- Luo, L., Zhang, J., Ye, C., Li, S., Duan, S., Wang, Z., Huang, H., Liu, Y., Deng, W., Mei, X., He, X., Yang, M., & Zhu, S. (2022). Foliar Pathogen Infection Manipulates Soil Health through Root Exudate-Modified Rhizosphere Microbiome. *Microbiology Spectrum*, 10(6). <https://doi.org/10.1128/spectrum.02418-22>
- Lv, M., Zhang, L., Wang, Y., Ma, L., Yang, Y., Zhou, X., Wang, L., Yu, X., & Li, S. (2024). Floral volatile benzenoids/phenylpropanoids: biosynthetic pathway, regulation and ecological value. *Horticulture Research*. <https://doi.org/10.1093/hr/uhae220>
- Ma, L., Shi, Y., Siemianowski, O., Yuan, B., Egner, T. K., Mirnezami, S. V., Lind, K. R., Ganapathysubramanian, B., Venditti, V., & Cademartiri, L. (2019). Hydrogel-based transparent soils for root phenotyping in vivo. *Proceedings of the National Academy of Sciences of the United States of America*, 166(22), 11063–11068. <https://doi.org/10.1073/pnas.1820334116>

- Macioszek, V. K., Jęcz, T., Ciereszko, I., & Kononowicz, A. K. (2023). Jasmonic Acid as a Mediator in Plant Response to Necrotrophic Fungi. In *Cells* (Vol. 12, Issue 7). MDPI. <https://doi.org/10.3390/cells12071027>
- Madbouly, A. K., Abdel-Aziz, M. S., & Abdel-Wahhab, M. A. (2017). Biosynthesis of nanosilver using *Chaetomium globosum* and its application to control *Fusarium* wilt of tomato in the greenhouse. *IET Nanobiotechnology*, 11(6), 702–708. <https://doi.org/10.1049/iet-nbt.2016.0213>
- Maffei, M. E. (2010). Sites of synthesis, biochemistry and functional role of plant volatiles. *South African Journal of Botany*, 76(4), 612–631. <https://doi.org/https://doi.org/10.1016/j.sajb.2010.03.003>
- Massalha, H., Korenblum, E., Tholl, D., & Aharoni, A. (2017). Small molecules below-ground: the role of specialized metabolites in the rhizosphere. *Plant Journal*, 90(4), 788–807. <https://doi.org/10.1111/tpj.13543>
- McBride, S. G., Choudoir, M., Fierer, N., & Strickland, M. S. (2020). Volatile organic compounds from leaf litter decomposition alter soil microbial communities and carbon dynamics. *Ecology*, 101(10), 1–9. <https://doi.org/10.1002/ecy.3130>
- Meents, A. K., & Mithöfer, A. (2020). Plant–Plant Communication: Is There a Role for Volatile Damage-Associated Molecular Patterns? In *Frontiers in Plant Science* (Vol. 11, p. 1538). Frontiers Media S.A. <https://doi.org/10.3389/fpls.2020.583275>
- Milla, R., Osborne, C. P., Turcotte, M. M., & Violle, C. (2015). Plant domestication through an ecological lens. *Trends in Ecology & Evolution*, 30(8), 463–469. <https://doi.org/10.1016/j.tree.2015.06.006>
- Mimmo, T., Hann, S., Jaitz, L., Cesco, S., Gessa, C. E., & Puschenreiter, M. (2011). Time and substrate dependent exudation of carboxylates by *Lupinus albus* L. and *Brassica napus* L. *Plant Physiology and Biochemistry*, 49(11), 1272–1278. <https://doi.org/10.1016/j.plaphy.2011.08.012>
- Monte, J., Abreu, A. C., Borges, A., Simões, L. C., & Simões, M. (2014). Antimicrobial activity of selected phytochemicals against *Escherichia coli* and *Staphylococcus aureus* and their biofilms. *Pathogens*, 3(2), 473–498. <https://doi.org/10.3390/pathogens3020473>
- Murungi, L. K., Kirwa, H., Coyne, D., Teal, P. E. A., Beck, J. J., & Torto, B. (2018). Identification of Key Root Volatiles Signaling Preference of Tomato over Spinach by the Root Knot Nematode *Meloidogyne incognita*. *Journal of Agricultural and Food Chemistry*, 66(28), 7328–7336. <https://doi.org/10.1021/acs.jafc.8b03257>
- Nalam, V. J., Shah, J., & Nachappa, P. (2013). Emerging role of roots in plant responses to aboveground insect herbivory. In *Insect Science* (Vol. 20, Issue 3, pp. 286–296). <https://doi.org/10.1111/1744-7917.12004>
- Naylor, D., DeGraaf, S., Purdom, E., & Coleman-Derr, D. (2017). Drought and host selection influence bacterial community dynamics in the grass root microbiome. *The ISME Journal*, 11(12), 2691–2704. <https://doi.org/10.1038/ismej.2017.118>
- Neal, A. L., Ahmad, S., Gordon-Weeks, R., & Ton, J. (2012). Benzoxazinoids in root exudates of maize attract *pseudomonas putida* to the rhizosphere. *PLoS ONE*, 7(4). <https://doi.org/10.1371/journal.pone.0035498>
- Niinemets, Ü., Kännaste, A., & Copolovici, L. (2013). Quantitative patterns between plant volatile emissions induced by biotic stresses and the degree of damage. *Frontiers in Plant Science*, 4(JUL), 1–15. <https://doi.org/10.3389/fpls.2013.00262>

- Nouri, C., Saadaoui, M., Morlevat, T., Esserti, S., Faize, L., Rifai, A., Tayeb, K., Smaili, A., Faize, M., & Venisse, J. S. (2024). Seed treatment with *Mortierella alpina* M01 promotes tomato growth and mitigates verticillium wilt and bacterial speck disease infections by potentiating plant antioxidant responses. *Journal of Plant Pathology*. <https://doi.org/10.1007/s42161-024-01669-1>
- Okutani, F., Hamamoto, S., Aoki, Y., Nakayasu, M., Nihei, N., Nishimura, T., Yazaki, K., & Sugiyama, A. (2020). Rhizosphere modelling reveals spatiotemporal distribution of daidzein shaping soybean rhizosphere bacterial community. *Plant Cell and Environment*, 43(4), 1036–1046. <https://doi.org/10.1111/pce.13708>
- Ota, R., Ohkubo, Y., Yamashita, Y., Ogawa-Ohnishi, M., & Matsubayashi, Y. (2020). Shoot-to-root mobile CEPD-like 2 integrates shoot nitrogen status to systemically regulate nitrate uptake in *Arabidopsis*. *Nature Communications*, 11(1). <https://doi.org/10.1038/s41467-020-14440-8>
- Owen, S. M., Clark, S., Pompe, M., & Semple, K. T. (2007). Biogenic volatile organic compounds as potential carbon sources for microbial communities in soil from the rhizosphere of *Populus tremula*. *FEMS Microbiology Letters*, 268(1), 34–39. <https://doi.org/10.1111/j.1574-6968.2006.00602.x>
- Ozimek, E., & Hanaka, A. (2021). *Mortierella* species as the plant growth-promoting fungi present in the agricultural soils. In *Agriculture (Switzerland)* (Vol. 11, Issue 1, pp. 1–18). MDPI AG. <https://doi.org/10.3390/agriculture11010007>
- Pang, Z., Chong, J., Zhou, G., de Lima Morais, D. A., Chang, L., Barrette, M., Gauthier, C., Jacques, P.-É., Li, S., & Xia, J. (2021). MetaboAnalyst 5.0: narrowing the gap between raw spectra and functional insights. *Nucleic Acids Research*, 49(W1), W388–W396. <https://doi.org/10.1093/nar/gkab382>
- Pang, Z., Lu, Y., Zhou, G., Hui, F., Xu, L., Viau, C., Spigelman, A. F., Macdonald, P. E., Wishart, D. S., Li, S., & Xia, J. (2024). MetaboAnalyst 6.0: towards a unified platform for metabolomics data processing, analysis and interpretation. *Nucleic Acids Research*, 52(W1), W398–W406. <https://doi.org/10.1093/nar/gkae253>
- Pangesti, N., Reichelt, M., van de Mortel, J. E., Kapsomenou, E., Gershenzon, J., van Loon, J. J. A., Dicke, M., & Pineda, A. (2016). Jasmonic Acid and Ethylene Signaling Pathways Regulate Glucosinolate Levels in Plants During Rhizobacteria-Induced Systemic Resistance Against a Leaf-Chewing Herbivore. *Journal of Chemical Ecology*, 42(12), 1212–1225. <https://doi.org/10.1007/s10886-016-0787-7>
- Pantigoso, H. A., Newberger, D., & Vivanco, J. M. (2022). The rhizosphere microbiome: Plant–microbial interactions for resource acquisition. In *Journal of Applied Microbiology* (Vol. 133, Issue 5, pp. 2864–2876). John Wiley and Sons Inc. <https://doi.org/10.1111/jam.15686>
- Park, I., Seo, Y. S., & Manna, M. (2023). Recruitment of the rhizo-microbiome army: assembly determinants and engineering of the rhizosphere microbiome as a key to unlocking plant potential. In *Frontiers in Microbiology* (Vol. 14). Frontiers Media S.A. <https://doi.org/10.3389/fmicb.2023.1163832>
- Park, S.-W., Kaimoyo, E., Kumar, D., Mosher, S., & Klessig, D. F. (2007). *Methyl Salicylate Is a Critical Mobile Signal for Plant Systemic Acquired Resistance*. <https://doi.org/10.1126/science.1147113>
- Patil, J. R., Mhatre, K. J., Yadav, K., Yadav, L. S., Srivastava, S., & Nikalje, G. C. (2024). Flavonoids in plant-environment interactions and stress responses. *Discover Plants*, 1(1). <https://doi.org/10.1007/s44372-024-00063-6>

- Paudel, S., Lin, P.-A., Foolad, M. R., Ali, J. G., Rajotte, E. G., & Felton, G. W. (2019). Induced Plant Defenses Against Herbivory in Cultivated and Wild Tomato. *Journal of Chemical Ecology*, 45(8), 693–707. <https://doi.org/10.1007/s10886-019-01090-4>
- Pawliszyn, J. (2012). 2 - Theory of Solid-Phase Microextraction. In J. Pawliszyn (Ed.), *Handbook of Solid Phase Microextraction* (pp. 13–59). Elsevier. <https://doi.org/10.1016/B978-0-12-416017-0.00002-4>
- Peng, W., Wu, W., Peng, J., Li, J., Lin, Y., Wang, Y., Tian, J., Sun, L., Liang, C., & Liao, H. (2018). Characterization of the soybean GmALMT family genes and the function of GmALMT5 in response to phosphate starvation. *Journal of Integrative Plant Biology*, 60(3), 216–231. <https://doi.org/10.1111/jipb.12604>
- Pérez-Jaramillo, J. E., Carrión, V. J., Bosse, M., Ferrão, L. F. V., De Hollander, M., Garcia, A. A. F., Ramírez, C. A., Mendes, R., & Raaijmakers, J. M. (2017). Linking rhizosphere microbiome composition of wild and domesticated *Phaseolus vulgaris* to genotypic and root phenotypic traits. *ISME Journal*, 11(10), 2244–2257. <https://doi.org/10.1038/ismej.2017.85>
- Pérez-Jaramillo, J. E., Mendes, R., & Raaijmakers, J. M. (2016). Impact of plant domestication on rhizosphere microbiome assembly and functions. *Plant Molecular Biology*, 90(6), 635–644. <https://doi.org/10.1007/s11103-015-0337-7>
- Philippot, L., Raaijmakers, J. M., Lemanceau, P., & Van Der Putten, W. H. (2013). Going back to the roots: The microbial ecology of the rhizosphere. In *Nature Reviews Microbiology* (Vol. 11, Issue 11, pp. 789–799). <https://doi.org/10.1038/nrmicro3109>
- Pichersky, E., Noel, J. P., & Dudareva, N. (2006). *Biosynthesis of Plant Volatiles: Nature's Diversity and Ingenuity*. <https://doi.org/10.1126/science.1118510>
- Pieterse, C. M. J., Zamioudis, C., Berendsen, R. L., Weller, D. M., Van Wees, S. C. M., & Bakker, P. A. H. M. (2014). Induced systemic resistance by beneficial microbes. *Annual Review of Phytopathology*, 52, 347–375. <https://doi.org/10.1146/annurev-phyto-082712-102340>
- Planchamp, C., Glauser, G., & Mauch-Mani, B. (2015). Root inoculation with *Pseudomonas putida* KT2440 induces transcriptional and metabolic changes and systemic resistance in maize plants. *Frontiers in Plant Science*, 5(JAN), 1–10. <https://doi.org/10.3389/fpls.2014.00719>
- Pluskal, T., Castillo, S., Villar-Briones, A., & Orešič, M. (2010). MZmine 2: Modular framework for processing, visualizing, and analyzing mass spectrometry-based molecular profile data. *BMC Bioinformatics*, 11(1), 395. <https://doi.org/10.1186/1471-2105-11-395>
- Pluskal, T., Korf, A., Smirnov, A., Schmid, R., Fallon, T. R., Du, X., & Weng, J.-K. (2020). Metabolomics Data Analysis Using MZmine. In R. Winkler (Ed.), *Processing Metabolomics and Proteomics Data with Open Software: A Practical Guide* (p. 0). The Royal Society of Chemistry. <https://doi.org/10.1039/9781788019880-00232>
- Price, C. T. D., Lee, I. R., & Gustafson, J. E. (2000). The effects of salicylate on bacteria. *The International Journal of Biochemistry & Cell Biology*, 32. www.elsevier.com/locate/ijbcb
- Raina, J. B., Fernandez, V., Lambert, B., Stocker, R., & Seymour, J. R. (2019). The role of microbial motility and chemotaxis in symbiosis. In *Nature Reviews Microbiology* (Vol. 17, Issue 5, pp. 284–294). Nature Research. <https://doi.org/10.1038/s41579-019-0182-9>

- Rajniak, J., Giehl, R. F. H., Chang, E., Murgia, I., Wirén, N. Von, & Sattely, E. S. (2018). response to iron deficiency in plants. *Nature Chemical Biology*, 14(May). <https://doi.org/10.1038/s41589-018-0019-2>
- Ramaroson, M. L., Koutouan, C., Helesbeux, J. J., Le Clerc, V., Hamama, L., Geoffriau, E., & Briard, M. (2022). Role of Phenylpropanoids and Flavonoids in Plant Resistance to Pests and Diseases. In *Molecules* (Vol. 27, Issue 23). MDPI. <https://doi.org/10.3390/molecules27238371>
- Rasmann, S., Chassin, E., Bilat, J., Glauser, G., & Reymond, P. (2015). Trade-off between constitutive and inducible resistance against herbivores is only partially explained by gene expression and glucosinolate production. *Journal of Experimental Botany*, 66(9), 2527–2534. <https://doi.org/10.1093/jxb/erv033>
- Rasmann, S., Köllner, T. G., Degenhardt, J., Hiltbold, I., Toepfer, S., Kuhlmann, U., Gershenzon, J., & Turlings, T. C. J. (2005). Recruitment of entomopathogenic nematodes by insect-damaged maize roots. *Nature*, 434(7034), 732–737. <https://doi.org/10.1038/nature03451>
- Raza, W., Wei, Z., Jousset, A., Shen, Q., & Friman, V.-P. (2021). *Extended Plant Metarhizobiome: Understanding Volatile Organic Compound Signaling in Plant-Microbe Metapopulation Networks*. <https://doi.org/10.1128/mSystems>
- Richter-Heitmann, T., Eickhorst, T., Knauth, S., Friedrich, M. W., & Schmidt, H. (2016). Evaluation of strategies to separate root-associated microbial communities: A crucial choice in rhizobiome research. *Frontiers in Microbiology*, 7(MAY). <https://doi.org/10.3389/fmicb.2016.00773>
- Rillig, M. C., Muller, L. A. H., & Lehmann, A. (2017). Soil aggregates as massively concurrent evolutionary incubators. *ISME Journal*, 11(9), 1943–1948. <https://doi.org/10.1038/ismej.2017.56>
- Rizaludin, M. S., Lee Díaz, A. S., Zweers, H., Raaijmakers, J. M., & Garbeva, P. (2025). Foliar infections by *Botrytis cinerea* modulate the tomato root volatilome and microbiome. *FEMS Microbiology Ecology*, 101(5). <https://doi.org/10.1093/femsec/fiaf042>
- Rizaludin, M. S., Stopnisek, N., Raaijmakers, J. M., & Garbeva, P. (2021). The chemistry of stress: Understanding the ‘cry for help’ of plant roots. In *Metabolites* (Vol. 11, Issue 6). MDPI AG. <https://doi.org/10.3390/metabo11060357>
- Ro, D. K., Ehltling, J., Keeling, C. I., Lin, R., Mattheus, N., & Bohlmann, J. (2006). Microarray expression profiling and functional characterization of AtTPS genes: Duplicated *Arabidopsis thaliana* sesquiterpene synthase genes At4g13280 and At4g13300 encode root-specific and wound-inducible (Z)- γ -bisabolene synthases. *Archives of Biochemistry and Biophysics*, 448(1–2), 104–116. <https://doi.org/10.1016/j.abb.2005.09.019>
- Rolfe, S. A., Griffiths, J., & Ton, J. (2019). Crying out for help with root exudates: adaptive mechanisms by which stressed plants assemble health-promoting soil microbiomes. In *Current Opinion in Microbiology* (Vol. 49, pp. 73–82). Elsevier Ltd. <https://doi.org/10.1016/j.mib.2019.10.003> <https://doi.org/https://doi.org/10.1016/j.mib.2019.10.003>
- Rosenkranz, T., Oburger, E., Baune, M., Weber, G., & Puschenreiter, M. (2021). Rhizosphere Root exudation of coumarins from soil-grown *Arabidopsis thaliana* in response to iron deficiency. *Rhizosphere*, 17(October 2020), 100296. <https://doi.org/10.1016/j.rhisph.2020.100296>

- Rudrappa, T., Czymmek, K. J., Paré, P. W., & Bais, H. P. (2008). Root-secreted malic acid recruits beneficial soil bacteria. *Plant Physiology*, 148(3), 1547–1556. <https://doi.org/10.1104/pp.108.127613>
- Santonja, M., Bousquet-Mélou, A., Greff, S., Ormeño, E., & Fernandez, C. (2019). Allelopathic effects of volatile organic compounds released from *Pinus halepensis* needles and roots. *Ecology and Evolution*, 9(14), 8201–8213. <https://doi.org/10.1002/ece3.5390>
- Savary, S., Willocquet, L., Pethybridge, S. J., Esker, P., McRoberts, N., & Nelson, A. (2019). The global burden of pathogens and pests on major food crops. *Nature Ecology and Evolution*, 3(3), 430–439. <https://doi.org/10.1038/s41559-018-0793-y>
- Scharf, B. E., Hynes, M. F., & Alexandre, G. M. (2016). Chemotaxis signaling systems in model beneficial plant–bacteria associations. *Plant Molecular Biology*, 90(6), 549–559. <https://doi.org/10.1007/s11103-016-0432-4>
- Schenkel, D., Lemfack, M. C., Piechulla, B., & Splivallo, R. (2015). A meta-analysis approach for assessing the diversity and specificity of belowground root and microbial volatiles. *Frontiers in Plant Science*, 6(September). <https://doi.org/10.3389/fpls.2015.00707>
- Schmid, N. B., Giehl, R. F. H., Döll, S., Mock, H. P., Strehmel, N., Scheel, D., Kong, X., Hider, R. C., & von Wirén, N. (2014). Feruloyl-CoA 6'-Hydroxylase1-dependent coumarins mediate iron acquisition from alkaline substrates in *Arabidopsis*. In *Plant Physiology* (Vol. 164, Issue 1, pp. 160–172). <https://doi.org/10.1104/pp.113.228544>
- Schmid, R., Heuckeroth, S., Korf, A., Smirnov, A., Myers, O., Dyrland, T. S., Bushuiev, R., Murray, K. J., Hoffmann, N., Lu, M., Sarvepalli, A., Zhang, Z., Fleischauer, M., Dührkop, K., Wesner, M., Hoogstra, S. J., Rudt, E., Mokshyna, O., Brungs, C., Pluskal, T. (2023). Integrative analysis of multimodal mass spectrometry data in MZmine 3. *Nature Biotechnology*, 41(4), 447–449. <https://doi.org/10.1038/s41587-023-01690-2>
- Schmidt, R., Cordovez, V., De Boer, W., Raaijmakers, J., & Garbeva, P. (2015). Volatile affairs in microbial interactions. *ISME Journal*, 9(11), 2329–2335. <https://doi.org/10.1038/ismej.2015.42>
- Schmidt, R., De Jager, V., Zühlke, D., Wolff, C., Bernhardt, J., Cankar, K., Beekwilder, J., Van Ijcken, W., Sleutels, F., De Boer, W., Riedel, K., & Garbeva, P. (2017). Fungal volatile compounds induce production of the secondary metabolite Sodorifen in *Serratia plymuthica* PRI-2C. *Scientific Reports*, 7(1), 1–14. <https://doi.org/10.1038/s41598-017-00893-3>
- Schmidt, R., Etalo, D. W., Jager, V. de, Gerards, S., Zweers, H., Boer, W. de, & Garbeva, P. (2016). Microbial small talk: Volatiles in fungal-bacterial interactions. *Frontiers in Microbiology*, 6(JAN), 1–12. <https://doi.org/10.3389/fmicb.2015.01495>
- Schmidt, R. L. (n.d.). *Volatile communication between fungi and bacteria*.
- Schorn, M. A., Verhoeven, S., Ridder, L., Huber, F., Acharya, D. D., Aksenov, A. A., Aleti, G., Moghaddam, J. A., Aron, A. T., Aziz, S., Bauermeister, A., Bauman, K. D., Baunach, M., Beemelmans, C., Beman, J. M., Berlanga-Clavero, M. V., Blacutt, A. A., Bode, H. B., Boullie, A., ... van der Hooft, J. J. J. (2021). A community resource for paired genomic and metabolomic data mining. In *Nature Chemical Biology* (Vol. 17, Issue 4, pp. 363–368). Nature Research. <https://doi.org/10.1038/s41589-020-00724-z>

- Schulz-Bohm, K., Gerards, S., Hundscheid, M., Melenhorst, J., De Boer, W., & Garbeva, P. (2018). Calling from distance: Attraction of soil bacteria by plant root volatiles. *ISME Journal*, 12(5), 1252–1262. <https://doi.org/10.1038/s41396-017-0035-3>
- Schulz-Bohm, K., Martín-Sánchez, L., & Garbeva, P. (2017). Microbial volatiles: Small molecules with an important role in intra- and inter-kingdom interactions. In *Frontiers in Microbiology* (Vol. 8, Issue DEC). Frontiers Media S.A. <https://doi.org/10.3389/fmicb.2017.02484>
- Semchenko, M., Saar, S., & Lepik, A. (2014). Plant root exudates mediate neighbour recognition and trigger complex behavioural changes. *New Phytologist*, 204(3), 631–637. <https://doi.org/10.1111/nph.12930>
- Sharifi, R., Jeon, J. S., & Ryu, C. M. (2022). Belowground plant-microbe communications via volatile compounds. In *Journal of Experimental Botany* (Vol. 73, Issue 2, pp. 463–486). Oxford University Press. <https://doi.org/10.1093/jxb/erab465>
- Singh, J., Aggarwal, R., Bashyal, B. M., Darshan, K., Parmar, P., Saharan, M. S., Hussain, Z., & Solanke, A. U. (2021). Transcriptome Reprogramming of Tomato Orchestrate the Hormone Signaling Network of Systemic Resistance Induced by *Chaetomium globosum*. *Frontiers in Plant Science*, 12. <https://doi.org/10.3389/fpls.2021.721193>
- Snoeren, T. A. L., Mumm, R., Poelman, E. H., Yang, Y., Pichersky, E., & Dicke, M. (2010). The herbivore-induced plant volatile methyl salicylate negatively affects attraction of the parasitoid *Diadegma semiclausum*. *Journal of Chemical Ecology*, 36(5), 479–489. <https://doi.org/10.1007/s10886-010-9787-1>
- Som, S., Willett, D. S., & Alborn, H. T. (2017). Dynamics of belowground volatile diffusion and degradation. *Rhizosphere*, 4, 70–74. <https://doi.org/10.1016/j.rhisph.2017.07.004>
- Strehmel, N., Böttcher, C., Schmidt, S., & Scheel, D. (2014). Profiling of secondary metabolites in root exudates of *Arabidopsis thaliana*. *Phytochemistry*, 108, 35–46. <https://doi.org/10.1016/j.phytochem.2014.10.003>
- Stringlis, I. A., Yu, K., Feussner, K., De Jonge, R., Van Bentum, S., Van Verk, M. C., Berendsen, R. L., Bakker, P. A. H. M., Feussner, I., & Pieterse, C. M. J. (2018). MYB72-dependent coumarin exudation shapes root microbiome assembly to promote plant health. *Proceedings of the National Academy of Sciences of the United States of America*, 115(22), E5213–E5222. <https://doi.org/10.1073/pnas.1722335115>
- Sumner, L. W., Amberg, A., Barrett, D., Beale, M. H., Beger, R., Daykin, C. A., Fan, T. W.-M., Fiehn, O., Goodacre, R., Griffin, J. L., Hankemeier, T., Hardy, N., Harnly, J., Higashi, R., Kopka, J., Lane, A. N., Lindon, J. C., Marriott, P., Nicholls, A. W., ... Viant, M. R. (2007). Proposed minimum reporting standards for chemical analysis. *Metabolomics*, 3(3), 211–221. <https://doi.org/10.1007/s11306-007-0082-2>
- Sun, J. Q., Jiang, H. L., & Li, C. Y. (2011). Systemin/jasmonate-mediated systemic defense signaling in tomato. In *Molecular Plant* (Vol. 4, Issue 4, pp. 607–615). Oxford University Press. <https://doi.org/10.1093/mp/ssr008>
- Svatoš, A., & Mock, H. P. (2013). MALDI Mass Spectrometric Imaging of Plants. *The Handbook of Plant Metabolomics*, 93–110. <https://doi.org/10.1002/9783527669882.ch5>
- Tholl, D. (2006). Terpene synthases and the regulation, diversity and biological roles of terpene metabolism. *Current Opinion in Plant Biology*, 9(3), 297–304. <https://doi.org/10.1016/j.pbi.2006.03.014>

- Tholl, D., Hossain, O., Weinhold, A., Röse, U. S. R., & Wei, Q. (2021). Trends and applications in plant volatile sampling and analysis. In *Plant Journal* (Vol. 106, Issue 2, pp. 314–325). Blackwell Publishing Ltd. <https://doi.org/10.1111/tpj.15176>
- Tholl, D., Sohrabi, R., Huh, J. H., & Lee, S. (2011). The biochemistry of homoterpenes - Common constituents of floral and herbivore-induced plant volatile bouquets. *Phytochemistry*, 72(13), 1635–1646. <https://doi.org/10.1016/j.phytochem.2011.01.019>
- Tieman, D., Zeigler, M., Schmelz, E., Taylor, M. G., Rushing, S., Jones, J. B., & Klee, H. J. (2010). Functional analysis of a tomato salicylic acid methyl transferase and its role in synthesis of the flavor volatile methyl salicylate. *The Plant Journal*, 62(1), 113–123. <https://doi.org/https://doi.org/10.1111/j.1365-313X.2010.04128.x>
- Trivedi, P., Leach, J. E., Tringe, S. G., Sa, T., & Singh, B. K. (2020). Plant–microbiome interactions: from community assembly to plant health. In *Nature Reviews Microbiology* (Vol. 18, Issue 11, pp. 607–621). Nature Research. <https://doi.org/10.1038/s41579-020-0412-1>
- Turlings, T. C. J., & Erb, M. (2018). Tritrophic Interactions Mediated by Herbivore-Induced Plant Volatiles: Mechanisms, Ecological Relevance, and Application Potential. *Annual Review of Entomology*, 63, 433–452. <https://doi.org/10.1146/annurev-ento-020117-043507>
- Turlings, T. C. J., Hiltbold, I., & Rasmann, S. (2012). The importance of root-produced volatiles as foraging cues for entomopathogenic nematodes. In *Plant and Soil* (Vol. 358, Issues 1–2, pp. 51–60). <https://doi.org/10.1007/s11104-012-1295-3>
- Tyagi, S., Lee, K. J., Shukla, P., & Chae, J. C. (2020). Dimethyl disulfide exerts antifungal activity against *Sclerotinia minor* by damaging its membrane and induces systemic resistance in host plants. *Scientific Reports*, 10(1). <https://doi.org/10.1038/s41598-020-63382-0>
- Valentinuzzi, F., Cesco, S., Tomasi, N., & Mimmo, T. (2015). Influence of different trap solutions on the determination of root exudates in *Lupinus albus* L. *Biology and Fertility of Soils*, 51(6), 757–765. <https://doi.org/10.1007/s00374-015-1015-2>
- van Dam, N. M., & Bouwmeester, H. J. (2016). Metabolomics in the Rhizosphere: Tapping into Belowground Chemical Communication. In *Trends in Plant Science* (Vol. 21, Issue 3, pp. 256–265). Elsevier Ltd. <https://doi.org/10.1016/j.tplants.2016.01.008>
- van Dam, N. M., Weinhold, A., & Garbeva, P. (2016). *Calling in the Dark: The Role of Volatiles for Communication in the Rhizosphere* (pp. 175–210). https://doi.org/10.1007/978-3-319-33498-1_8
- van der Meij, A., Elsayed, S. S., Du, C., Willemse, J., Wood, T. M., Martin, N. I., Raaijmakers, J. M., & van Wezel, G. P. (2023). The plant stress hormone jasmonic acid evokes defensive responses in streptomycetes. *Applied and Environmental Microbiology*, 89(11). <https://doi.org/10.1128/aem.01239-23>
- van Schie, C. C. N., Haring, M. A., & Schuurink, R. C. (2007). Tomato linalool synthase is induced in trichomes by jasmonic acid. *Plant Molecular Biology*, 64(3), 251–263. <https://doi.org/10.1007/s11103-007-9149-8>
- Vannier, N., Agler, M., & Hacquard, S. (2019). Microbiota-mediated disease resistance in plants. *PLoS Pathogens*, 15(6), 1–7. <https://doi.org/10.1371/journal.ppat.1007740>

- Vaughan, M. M., Christensen, S., Schmelz, E. A., Huffaker, A., Mcauslane, H. J., Albarn, H. T., Romero, M., Allen, L. H., & Teal, P. E. A. (2015). *Accumulation of terpenoid phytoalexins in maize roots is associated with drought tolerance*. <https://doi.org/10.1111/pce.12482>
- Vaughan, M. M., Wang, Q., Webster, F. X., Kiemle, D., Hong, Y. J., Tantillo, D. J., Coates, R. M., Wray, A. T., Askew, W., O'Donnell, C., Tokuhisa, J. G., & Tholl, D. (2013). Formation of the unusual semivolatile diterpene rhizathalene by the Arabidopsis class I terpene synthase TPS08 in the root stele is involved in defense against belowground herbivory. *Plant Cell*, 25(3), 1108–1125. <https://doi.org/10.1105/tpc.112.100057>
- Vijayabharathi, R., Gopalakrishnan, S., Sathya, A., Vasanth Kumar, M., Srinivas, V., & Mamta, S. (2018). *Streptomyces* sp. as plant growth-promoters and host-plant resistance inducers against Botrytis cinerea in chickpea. *Biocontrol Science and Technology*, 28(12), 1140–1163. <https://doi.org/10.1080/09583157.2018.1515890>
- Vogt, T. (2010). Phenylpropanoid biosynthesis. In *Molecular Plant* (Vol. 3, Issue 1, pp. 2–20). Oxford University Press. <https://doi.org/10.1093/mp/ssp106>
- Vos, M., Wolf, A. B., Jennings, S. J., & Kowalchuk, G. A. (2013). Micro-scale determinants of bacterial diversity in soil. *FEMS Microbiology Reviews*, 37(6), 936–954. <https://doi.org/10.1111/1574-6976.12023>
- Wang, C., Xing, J., Chin, C.-K., Ho, C.-T., & Martin, C. E. (2001). Modification of fatty acids changes the flavor volatiles in tomato leaves. *Phytochemistry*, 58(2), 227–232. [https://doi.org/https://doi.org/10.1016/S0031-9422\(01\)00233-3](https://doi.org/https://doi.org/10.1016/S0031-9422(01)00233-3)
- Wang, D., He, X., Baer, M., Lami, K., Yu, B., Tassinari, A., Salvi, S., Schaaf, G., Hochholdinger, F., & Yu, P. (2024). Lateral root enriched Massilia associated with plant flowering in maize. *Microbiome*, 12(1). <https://doi.org/10.1186/s40168-024-01839-4>
- Wang, X., Zhang, J., Lu, X., Bai, Y., & Wang, G. (2024). Two diversities meet in the rhizosphere: root specialized metabolites and microbiome. In *Journal of Genetics and Genomics* (Vol. 51, Issue 5, pp. 467–478). Institute of Genetics and Developmental Biology. <https://doi.org/10.1016/j.jgg.2023.10.004>
- Wang, Y., & Lambers, H. (2020). Root-released organic anions in response to low phosphorus availability: recent progress, challenges and future perspectives. *Plant and Soil*, 447(1–2), 135–156. <https://doi.org/10.1007/s11104-019-03972-8>
- Wardencki, W., Curyło, J., & Namieśnik, J. (2007). Trends in solventless sample preparation techniques for environmental analysis. *Journal of Biochemical and Biophysical Methods*, 70(2), 275–288. <https://doi.org/https://doi.org/10.1016/j.jbbm.2006.07.004>
- Weisskopf, L., Schulz, S., & Garbeva, P. (2021). Microbial volatile organic compounds in intra-kingdom and inter-kingdom interactions. In *Nature Reviews Microbiology* (Vol. 19, Issue 6, pp. 391–404). Nature Research. <https://doi.org/10.1038/s41579-020-00508-1>
- Wenke, K., Kai, M., & Piechulla, B. (2010). Belowground volatiles facilitate interactions between plant roots and soil organisms. In *Planta* (Vol. 231, Issue 3, pp. 499–506). <https://doi.org/10.1007/s00425-009-1076-2>

- Xiao, X., Fan, M., Wang, E., Chen, W., & Wei, G. (2017). Interactions of plant growth-promoting rhizobacteria and soil factors in two leguminous plants. *Applied Microbiology and Biotechnology*, 101(23–24), 8485–8497. <https://doi.org/10.1007/s00253-017-8550-8>
- Xing, Z., Zhang, Z., Zhao, Y., Biere, A., Liu, S., Shi, Y., & Ding, J. (2024). Foliar herbivory-enhanced mycorrhization is associated with increased levels of lipids in root and root exudates. *Journal of Ecology*, 112(4), 701–716. <https://doi.org/10.1111/1365-2745.14272>
- Xiong, Y. W., Li, X. W., Wang, T. T., Gong, Y., Zhang, C. M., Xing, K., & Qin, S. (2020). Root exudates-driven rhizosphere recruitment of the plant growth-promoting rhizobacterium *Bacillus flexus* KLBMP 4941 and its growth-promoting effect on the coastal halophyte *Limonium sinense* under salt stress. *Ecotoxicology and Environmental Safety*, 194(January). <https://doi.org/10.1016/j.ecoenv.2020.110374>
- Yahyaa, M., Tholl, D., Cormier, G., Jensen, R., Simon, P. W., & Ibdah, M. (2015). Identification and Characterization of Terpene Synthases Potentially Involved in the Formation of Volatile Terpenes in Carrot (*Daucus carota* L.) Roots. *Journal of Agricultural and Food Chemistry*, 63(19), 4870–4878. <https://doi.org/10.1021/acs.jafc.5b00546>
- Yan, D., Cao, A., Wang, Q., Li, Y., Canbin, O., Guo, M., & Guo, X. (2019). Dimethyl disulfide (DMDS) as an effective soil fumigant against nematodes in China. *PLoS ONE*, 14(10). <https://doi.org/10.1371/journal.pone.0224456>
- Yang, L., Qian, X., Zhao, Z., Wang, Y., Ding, G., & Xing, X. (2024). Mechanisms of rhizosphere plant-microbe interactions: molecular insights into microbial colonization. In *Frontiers in Plant Science* (Vol. 15). Frontiers Media SA. <https://doi.org/10.3389/fpls.2024.1491495>
- Yang, Y., Li, Y., Mei, X., Yang, M., Huang, H., Du, F., Wu, J., He, Y., Sun, J., Wang, H., He, X., Zhu, S., Li, Y., & Liu, Y. (2022). Antimicrobial Terpenes Suppressed the Infection Process of *Phytophthora* in Fennel-Pepper Intercropping System. *Frontiers in Plant Science*, 13. <https://doi.org/10.3389/fpls.2022.890534>
- Yazaki, K., Arimura, G. I., & Ohnishi, T. (2017). “Hidden” terpenoids in plants: Their biosynthesis, localization and ecological roles. *Plant and Cell Physiology*, 58(10), 1615–1621. <https://doi.org/10.1093/pcp/pcx123>
- Yi, H. S., Heil, M., Adame-Álvarez, R. M., Ballhorn, D. J., & Ryu, C. M. (2011). A cry for help from leaf to root. *Plant Physiology*, 6(4), 1192–1194. <https://doi.org/10.1104/pp.109.144782>
- Yi, H. S., Yang, J. W., Ghim, S. Y., & Ryu, C. M. (2011). A cry for help from leaf to root: Aboveground insect feeding leads to the recruitment of rhizosphere microbes for plant self-protection against subsequent diverse attacks. *Plant Signaling and Behavior*, 6(8), 1192–1194. <https://doi.org/10.4161/psb.6.8.15780>
- Yin, C., Casa Vargas, J. M., Schlatter, D. C., Hagerty, C. H., Hulbert, S. H., & Paulitz, T. C. (2021). Rhizosphere community selection reveals bacteria associated with reduced root disease. *Microbiome*, 9(1). <https://doi.org/10.1186/s40168-020-00997-5>

- Yin, C., Hulbert, S. H., Schroeder, K. L., Mavrodi, O., Mavrodi, D., Dhingra, A., Schillinger, W. F., & Paulitz, T. C. (2013). Role of bacterial communities in the natural suppression of *Rhizoctonia solani* bare patch disease of wheat (*Triticum aestivum* L.). *Applied and Environmental Microbiology*, 79(23), 7428–7438. <https://doi.org/10.1128/AEM.01610-13>
- Yuan, H., Cao, G., Hou, X., Huang, M., Du, P., Tan, T., Zhang, Y., Zhou, H., Liu, X., Liu, L., Jiangfang, Y., Li, Y., Liu, Z., Fang, C., Zhao, L., Fernie, A. R., & Luo, J. (2022). Development of a widely targeted volatilomics method for profiling volatiles in plants. *Molecular Plant*, 15(1), 189–202. <https://doi.org/10.1016/j.molp.2021.09.003>
- Yuan, J., Zhang, N., Huang, Q., Raza, W., Li, R., Vivanco, J. M., & Shen, Q. (2015). Organic acids from root exudates of banana help root colonization of PGPR strain *Bacillus amyloliquefaciens* NJN-6. *Scientific Reports*, 5. <https://doi.org/10.1038/srep13438>
- Yuan, J., Zhao, J., Wen, T., Zhao, M., Li, R., Goossens, P., Huang, Q., Bai, Y., Vivanco, J. M., Kowalchuk, G. A., Berendsen, R. L., & Shen, Q. (2018). Root exudates drive the soil-borne legacy of aboveground pathogen infection. *Microbiome*, 6(1). <https://doi.org/10.1186/s40168-018-0537-x>
- Zhalnina, K., Louie, K. B., Hao, Z., Mansoori, N., da Rocha, U. N., Shi, S., Cho, H., Karaoz, U., Loqué, D., Bowen, B. P., Firestone, M. K., Northen, T. R., & Brodie, E. L. (2018). Dynamic root exudate chemistry and microbial substrate preferences drive patterns in rhizosphere microbial community assembly. *Nature Microbiology*, 3(4), 470. <https://doi.org/10.1038/s41564-018-0129-3>
- Zhao, N., Guan, J., Ferrer, J. L., Engle, N., Chern, M., Ronald, P., Tschaplinski, T. J., & Chen, F. (2010). Biosynthesis and emission of insect-induced methyl salicylate and methyl benzoate from rice. *Plant Physiology and Biochemistry*, 48(4), 279–287. <https://doi.org/10.1016/j.plaphy.2010.01.023>
- Znój, A., Grzesiak, J., Gawor, J., Gromadka, R., & Chwedorzewska, K. J. (2022). Highly specialized bacterial communities within three distinct rhizocompartments of Antarctic hairgrass (*Deschampsia antarctica* Desv.). *Polar Biology*, 45(5), 833–844. <https://doi.org/10.1007/s00300-022-03027-2>