Article Type: Mini Review

Received: 17/11/2020

Published: 25/11/2020

Open Access Journal of
Biogeneric Science and Research
ISSN 2692-1081

DOI: 10.46718/JBGSR.2020.05.000128

Antibiotic Compounds Present in Suppressive Soils against Fungal and Oomycetes Plant Pathogens: A Mini-Review

María Belén Colavolpe*

Instituto Nacional de Investigação Agrária e Veterinária, I. P. Oeiras, Portugal

*Corresponding author: María Belén Colavolpe, Instituto Nacional de Investigação Agrária e Veterinária, I. P. Oeiras, Portugal

Abstract

Background: The plants are part of a complex environment that includes microorganisms in the soil and covers different ecological interactions. Filamentous plant pathogens can attack plants to obtain nutrients for growth and reproduction. The soil within its complex microbial communities and the production of bioactive compounds; currently represent an interesting scientific subject for searching novel bioproducts of biotechnological interest. Certain bacteria of the microbiota can protect plants against pathogens using different mechanisms. The protective effect can be directly due to antibiotic compounds production or indirect by promoting plant defense as induced systemic resistance. This mini-review describes some aspects of the direct effect: the production of antibiotic compounds by antagonist bacteria, mainly of the genus *Bacillus*, *Burkholderia*, and *Pseudomonas* in suppressive soils.

Keywords: Antagonist Bacteria; Plant Disease; Volatile Compounds and Antibiotic Peptides.

Introduction

The plants are part of a rich ecosystem in the soil [1], where bacteria generally colonize the plant rhizosphere and, sometimes, the endosphere. Some beneficial effects for plants may include assistance in getting nutrients and promoting plant growth by modulating growth-related hormones [2]. Other benefits include the reduction of damage caused by phytopathogen [3]. Filamentous plant pathogens can severely attack plants, and in agriculture, this could lead to high economic annual losses [4]. The suppressive soils support soil microorganisms as the first defense against soilborne pathogens. General suppressive soils have a high total microbial biomass, resulting in low specificity against specific pathogens. This condition is dependent on the quality and quantity of soil organic matter, and the crop present that could enhance populations of beneficial microbes to antagonize associated pathogens, primarily by occupying plant infection sites [5]. However, specific suppressive soils have a high concentration of specific microbial species and result in high protection against specific pathogens [6].

Cultural practices in agriculture have a strong influence on soil health because these could affect soil physicochemical characteristics and microbial communities. Some cultural practices are used to improve soil health and can, in some cases, increase soil disease suppression [7]. According to Schlatter et al. [6], the relationship between soil properties and soil suppressiveness has not been deeply studied. Many different abiotic or biotic soil characteristics have been used to describe suppressiveness, but there is a lack of reliable descriptors.

The plant protection of certain bacteria against pathogens includes a wide range of mechanisms: antibiosis, competition for colonization sites, nutrients and minerals, parasitism, and cell lysis [8]. The protection can be caused by direct action due to antibiotic compounds or indirectly by promoting plant defense as induced systemic resistance [9]. The bacteria biological activity is also related to secondary metabolites production, low molecular mass products not essential for bacteria survival produced by secondary metabolism during the late growth phase (idiophase) [10]. These compounds are generally involved in the antibiosis or

perform synergism with other inhibitors [11].

This mini-review focuses on some conditions needed to maintain a suppressive soil and the antibiotic compounds produced by the most studied bacteria groups. Because of these molecules' wide diversity, the classification is complex, and several criteria could be taken [12]. In this overview, the work description considers the bioactive metabolites as volatile compounds and non-ribosomal peptides in an integrated and general way.

Physicochemical Characteristics and Antimicrobial Compounds from the Most Studied Bacteria Groups of Suppressive Soils

The suppressive effect could be more likely related to a combination of biotic and abiotic parameters in soils [13]. Chemical and physical attributes of soil, including pH, organic matter, and clay content, can impact soil microbial activity [14]. The degree of suppressiveness is related to physical soil conditions, fertility level, water supply, populations of microorganisms and soil management [15]. Soil texture and structure affect holding capacity, nutrient status, gas exchange, and root growth related to the percentage of sand, silt, and clay particles in the soil [13]. An example of a detrimental physical soil characteristic for disease suppressiveness is low sand content levels and high incidence of *Fusarium* spp. and *Armillaria* spp. root disease on lodgepole pine. Another example is poor soil aeration, associated with cavity spot (*Pythium* spp.) disease in carrot, as well as pea root rot complex (*Fusarium* spp.), also affected by soil compaction [17].

Soil organisms are concentrated in the top 10 cm of soil; the minimum tillage use maintains the biota near the surface instead of diluting them through a greater depth [14]. Stubble retention in the soil has an essential effect on the level of organic material (carbon). Carbon-based material represents an energy source for soil biota. It helps in the fast multiplication of the soil population and reduces moisture evaporation, increasing some antagonist organisms [17]. The rotation could be another effective agricultural practice for giving the soil a break of some crops. For example, in cereals, a significant reduction of root disease was found when specific rotation was used [13].

The general suppression in soils is not related to a specific group of microorganisms; many factors and populations cooperate to inhibit the pathogen or the disease's development. The disease suppression might be related to soil microorganisms specific functions; many authors have found consistent correlations among specific functional parameters and disease suppression. One of the best examples is the production of antibiotic compounds

[13]. Bacteria from the plant environment can produce different molecules with antagonist activity against fungal and oomycetes plant pathogens. Many of these beneficial microorganisms can be selected with a relatively high effectivity and multiplied on artificial media [18] to study its compounds. However, in vitro cultures' main disadvantage is that metabolites' production depends on medium nutrient concentration and composition, generally higher in culture media than in natural habitats, conditions that could not correctly predict the real antagonism effect [19,20]. Nonetheless, there has been an increasing interest in discovering the metabolites of biocontrol agents for plant disease control. According to Colavolpe et al. (b) [21], the use of active compounds can overcome the challenge associated with the use of living microorganisms for the biocontrol purpose.

Bacteria from the *Bacillus* genus inhabit many different habitats [22] and offer many compounds displaying a broad range of antagonist functions [23]. This enormous versatility increases the industrial and environmental interest, especially in *B. subtilis* strains [24]. The volatile compounds include benzene compounds, pentadecane, tetradecane, and some ketones, which are of particular interest due to their long-distance action [25,26]. Volatile fatty acids and their derivatives are the most important produced by microbes, and in the case of *B. subtilis*, represent up to 87% of known antimicrobial produced by the bacteria [27].

According to Méndez-Bravo et al. [26], a bacteria isolate (A8a) closely related to *B. acidiceler* can inhibit the oomycete *Phytophthora cinnamomi* growth *in vitro* by 76% through the production of volatile compounds identified as 6,10-dimethyl-5,9-undecadien-2-one, 2,3,5-trimethylpyrazine, and 3-amino-1,3-oxazolidin-2-one. The total ion chromatogram of isolate A8a displayed components identified to belong to the chemical categories of ketones, aldehydes, alkyls, sulfoxides, pyrazines, and alcohols [25]. The strain G341 of *B. velezensis* produced antifungal volatiles and inhibited the mycelial growth of *Sclerotinia sclerotiorum*, *Rhizoctonia solani*, and *Botrytis cinerea*. Volatile profiles indicated that strain G341 produces three volatile compounds: dimethylsulfoxide, 1-butanol, and 3-hydroxy-2-butanone (acetoin) [23].

Some of the more diverse plant-associated bacteria are β -proteobacteria belonging to the genus *Burkholderia* [28]. The volatile profile of *B. tropica* strain MT0431 was studied by Tenorio-Salgado et al. [29], and different compounds were identified, including sulfur metabolites, dimethyldisulfide, toluene, and terpenoid compounds, such as α -pinene, limonene, and ocimene. Several of

these volatile compounds have been previously detected in cultures of many strains of *Pseudomonas* spp and *B. cepacia* [29]. Many soil-derived *Pseudomonas* strains are potentially useful biocontrol agents of oomycetes. These include *P. putida*, *P. fluorescens*, *Pseudomonas* sp. SH-C52 and *P. chlororaphis* [30]. Dimethyl disulfide and other sulfur-containing compounds emitted by *Pseudomonas* species were recently shown to stop the growth of *P. infestans*. Other volatile compounds, such as 1-Undecene [31], can also reduce sporangia formation and zoospores' release in *P. infestans*. The volatile compound 2-phenyl ethanol inhibited the mycelial growth of *Penicillium digitatum*, *P. italicum*, and *B. cinerea*. Additionally, the 2,3,5-trimethylpyrazine compound has been identified as an abundant component in several volatile profiles from fungistatic soils against *Rhizoctonia* and *Fusarium* phytopathogens [26].

Important bioactive molecules from the genus *Bacillus* are non-ribosomally synthesized peptides [9], metabolites with very complex biosynthesis mechanisms catalyzed by non-ribosomal peptide synthetases, large enzyme modular structure complexes, each module being in charge of incorporating particular amino acid [22]. *B. subtilis* and *B. amyloliquefaciens* can produce different lipopeptides in which antifungal activity varies according to the targeted phytopathogen [9]. The representative lipopeptides can be classified into three families based on their amino acid configuration: surfactin, iturins (mycosubtilin, iturin A, and bacillomycin), and fengycin. Both iturins and fengycin have antifungal activities [32]; meanwhile, the surfactin family has antiviral activity. Some antifungal activity presents synergistic actions when applied in combination with iturin A or fengycin [9]. *B. amyloliquefaciens* synthesizes iturin and fengycin and can inhibit the growth of *Alternaria panax*, *B. cinerea*, *Colletotrichum orbiculare*, *P. digitatum*, *F. oxysporum*, *F. solani*, *Verticillium dahlia*, *P. parasitica* [21], *Ralstonia solanacearum*, and *R. solani* [20]. Most important molecules from this group, circular lipopeptides from surfactin, iturin, and fengycin families [9], affect the target cells of the pathogens on the membrane level [22].

Another antibiotic lipopeptide, called viscosinamide, is produced by *P. fluorescens*. It has been shown to increase membrane permeability in plant cells facilitating pectolytic attack and has been further reported to act as a biosurfactant. *Pythium ultimum* and *R. solani* resulted in inhibited by specific *Pseudomonas* *in vitro* antagonism [20]. Antibiotics isolated from strains of *P. cepacia* include cepacin A, cepacin B, altericidins, 2-[2-heptenyl]-3-methyl-4-quinolinol, pyrrolnitrin [3-chloro-4-(2'-nitro-3'-chlorophenyl)-pyrrole], and 2-[2-nonenyl]-3-methyl-4-quinolinol [33].

The analysis of fungal pathogens co-cultivated with antagonistic bacteria producing the mentioned compounds showed changes in hyphal morphology, including hyphal swelling, distortion, large amounts of balloon-shaped cells, and cytoplasm protoplasm aggregation. Degradation of fungal cell walls, cell breakage, leakage of intracellular substances, alterations in hyphal morphology, lysis of fungal hyphae, vacuolization, granulation in mycelium structures, and ruptured of mycelia were also detected changes [29]. These effects on pathogen cells result from direct defense due to the production of antibiotic compounds by bacteria. This potent inhibition leads to thinking that specific bacteria antagonistic compounds are key for supporting future biotechnological research in controlling plant disease.

Conclusion

Chemical and physical attributes of soil can impact the microbial activity and consequently, its suppressiveness due to the promotion of bacteria groups with antagonistic effects. These effects can be directly to plant pathogens as a result of the action of bacterial antibiotic compounds. The production of antibiotic compounds is necessary to preserve the health and the antagonism in soils against plant pathogens. This mini-review concludes and strongly supports the idea that bacteria's antagonistic compounds, mainly of the genus *Bacillus*, *Burkholderia*, and *Pseudomonas*, represent crucial tools for supporting future biotechnological research in controlling plant disease.

References

1. De Lima Naoe AM, Koshy Naoe L, Mucci Peluzio J (2020) Interactions of Plant Microbiomes: A Review on the Azospirillum Brasilense. Op Acc J Bio Sci & Res 4(1).
2. Gravel V, Antoun H, Tweddell RJ (2007) Growth stimulation and fruit yield improvement of greenhouse tomato plants by inoculation with *Pseudomonas putida* or *Trichoderma atroviride*: possible role of indole acetic acid (IAA). Soil Biol Biochem 39: 1968-1977.
3. Kloepper JW, Ryu CM (2006) Microbial Root Endophytes. In: Ajit Varma (ed) Soil Biology, Springer, Germany, pp. 33-52.
4. Vos I, Pieterse C, van Wees S (2013) Costs and benefits of hormone-regulated plant defenses. Plant Pathol 62: 43-55.
5. van Elsas JD, Costa R, Jansson J, Sjöling S, Bailey M, et al. (2008) The metagenomics of disease-suppressive soils – experiences from the METACONTROL project. Trends in Biotechnology 26(11):591-601.
6. Schlatter D, Kinkel L, Thomashow L, Weller D, Paulitz T (2017) Disease Suppressive Soils: New Insights from the Soil Microbiome. Phytopathology 107(11):1284-1297.
7. Cook RJ (2014) Plant health management: Pathogen suppressive soils. In: Encyclopedia of Agriculture and Food Systems. Elsevier,

Amsterdam, Netherlands, pp. 441-455.

8. Whipps J (2001) Microbial interactions and biocontrol in the rhizosphere. *J Exp Bot* 52: 487-511.
9. Asari S, Ongena M, Debois D, De Pauw E, Chen K, et al. (2017) Insights into the molecular basis of biocontrol of Brassica pathogens by *Bacillus amyloliquefaciens* UCMB5113 lipopeptides. *Ann Bot*. Oct 17;120(4):551-562.
10. Gokulan K, Khare S, Cerniglia C (2014) Metabolic pathways: production of secondary metabolites of bacteria. In: Batt, C. A., Tortorello, M. L. (Eds.), *Encyclopedia of food microbiology*, vol 2. Elsevier Ltd, Academic Press pp. 561-569.
11. Colavolpe (a) MB, Villarreal NM, Langer SE, Romero FM, Martínez GA, et al. (2020) *Burkholderia* sp. Strain AU4i Promotes Arabidopsis Growth and Increases Plant Defence Response to Necrotrophic Pathogens. *J Plant Growth Regul*.
12. Wang T, Liang Y, Wu M, Chen Z, Lin J, et al (2015) Natural products from *Bacillus subtilis* with antimicrobial properties. *Chin. J. Chem. Eng* 23: 744-754.
13. Sarki A, Mirjat MS, Mahessar AA, Kori SM, Qureshi AL (2014) Determination of saturated hydraulic conductivity of different soil texture materials. *IOSR Journal of Agriculture and Veterinary Science*, 7(12): 56-62.
14. Höper H, Alabouvette C (1996) Importance of physical and chemical soil properties in the suppressiveness of soils to plant diseases. *European Journal of Soil Biology*. 32(1): 41-58.
15. Persson L, Olsson S (2000) Abiotic characteristics of soils suppressive to *Aphanomyces* root rot. *Soil Biology and Biochemistry*, 32(8-9): 1141-1150.
16. Mallett KI, Maynard DG (1998) *Armillaria* root disease, stand characteristics, and soil properties in young lodgepole pine. *Forest Ecology and Management*, 105: 37-44.
17. Janvier C, Villeneuve F, Alabouvette C, Edel-Hermann V, Mateille T, et al. (2007) Soil health through soil disease suppression: Which strategy from descriptors to indicators? *Soil Biology and Biochemistry*, 39(1): 1-23.
18. Köhl J, Kolnaar R, Ravensberg WJ (2019) Mode of Action of Microbial Biological Control Agents Against Plant Diseases: Relevance Beyond Efficacy. *Front. Plant Sci*. 10: 845.
19. Knudsen IMB, Hockenhull J, Funck Jensen D, Gerhardson B, Hökeberg M, et al. (1997) Selection of biological control agents for controlling soil and seed-borne diseases in the field. *Eur. J. Plant Pathol* 103: 775-784.
20. Nielsen MN, Sørensen J, Fels J, Pedersen HC (1998) Secondary metabolite- and endochitinase-dependent antagonism toward plant-pathogenic microfungi of *Pseudomonas fluorescens* isolates from sugar beet rhizosphere. *Applied and Environmental Microbiology* 64: 3563-3569.
21. Colavolpe (b) MB, de Castro Silva M, Maguire VG, Costa A, Videira e Castro I, et al. (2020) Antagonistic compounds from controversial bacteria with suppressing effects on the diseases caused by *Phytophthora cinnamomi*. *Archives of Phytopathology and Plant Protection*.
22. Fira D, Dimkic I, Beric T, Lozo J, Stankovic S. (2018) Biological control of plant pathogens by *Bacillus* species. *J. Biotechnol* 285: 44-55.
23. Lim SM, Yoon MY, Choi GJ, Choi YH, Jang KS, et al. (2017) Diffusible and Volatile Antifungal Compounds Produced by an Antagonistic *Bacillus velezensis* G341 against Various Phytopathogenic Fungi. *The plant pathology journal* 33(5): 488-498.
24. Caulier S, Nannan C, Gillis A, Licciardi F, Bragard C, et al. (2019) Overview of the Antimicrobial Compounds Produced by Members of the *Bacillus subtilis* Group. *Front Microbiol* 10:302.
25. Effmert U, Kalderas J, Warnke R, Piechulla B (2012) Volatile mediated interactions between bacteria and fungi in the soil. *J Chem Ecol* 38: 665-703.
26. Méndez-Bravo A, Cortazar-Murillo EM, Guevara-Avendaño E, Ceballos-Luna O, Rodríguez-Haas B, (2018) Plant growth-promoting rhizobacteria associated with avocado display antagonistic activity against *Phytophthora cinnamomi* through volatile emissions. *PLoS ONE* 13(3): e0194665.
27. Adak S, Aulak KS, Stuehr DJ (2002) Direct evidence for nitrate oxide production by a nitric-oxide synthase-like protein from *Bacillus subtilis*. *Journal of Biological Chemistry*. 277: 16167-16171.
28. Poupin MJ, Timmermann T, Vega A, Zuñiga A, González B (2013) Effects of the Plant Growth-Promoting Bacterium *Burkholderia phytofirmans* PsJN throughout the Life Cycle of *Arabidopsis thaliana*. *PLOS One* 8: e69435.
29. Tenorio-Salgado S, Tinoco R, Vazquez-Duhalt R, Caballero-Mellado J, Perez-Rueda E (2013) Identification of volatile compounds produced by the bacterium *Burkholderia tropica* that inhibit the growth of fungal pathogens. *Bioengineered* 4(4): 236-243.
30. Wagner A, Norris S, Chatterjee P, Morris PF, Wildschutte H (2018) Aquatic pseudomonads inhibit oomycete plant pathogens of glycine max. *Front. Microbiol*. 9: 1007
31. Lazazzara V, Perazzolli M, Pertot I, Biasioli F, Puopolo G, Cappellin L (2017) Growth media affect the volatile and antimicrobial activity against *Phytophthora infestans* in four *Lysobacter* type strains. *Microbiol. Res* 201: 52-62.
32. Guo Q, Dong W, Li S, Lu X, Wang P, et al. (2014) Fengycin produced by *Bacillus subtilis* NCD-2 plays a major role in biocontrol of cotton seedling damping-off disease. *Microbiol Res*. 169(7-8): 533-540.
33. Jayaswal RK, Fernandez M, Upadhyay RS, Visintin L, Kurz M, et al. (1993) Antagonism of *Pseudomonas cepacia* against phytopathogenic fungi. *Current Microbiology* 26: 17-22.

***Corresponding author:** María Belén Colavolpe, Email: mbelen.colavolpe@iniav.pt

Next Submission with BGSR follows:

- Rapid Peer Review
- Reprints for Original Copy
- E-Prints Availability
- Below URL for auxiliary Submission Link: <https://biogenericpublishers.com/submit-manuscript/>

Citation: María Belén Colavolpe, Antibiotic Compounds Present in Suppressive Soils against Fungal and Oomycetes Plant Pathogens: A Mini-Review.

Op Acc J Bio Sci & Res 5(4)-2020.

DOI: 10.46718/JBGR.2020.05.000128