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COMPOST AS A RESERVOIR OF BACTERIA WITH BIOCONTROL POTENTIAL AGAINST PHYTOPATHOGENIC FUNGI

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ABSTRACT

Plant diseases caused by phytopathogenic fungi lead to significant economic losses in agriculture. Bacteria isolated from compost have been shown to exhibit suppressive activity against these pathogens. The aim of this study was to isolate bacteria from five compost samples differing in origin and physicochemical properties and to evaluate their biocontrol potential. A total of 38 bacterial isolates were obtained, of which 12 were selected for further characterization. These isolates were subjected to morphological and biochemical analyses, identified using MALDI-TOF MS, and tested for their ability to produce siderophores and inhibit selected phytopathogenic fungi (*Botrytis cinerea, Penicillium olsonii, Fusarium oxysporum,* and *Alternaria alternata*). Eight isolates demonstrated the ability to produce siderophores. The highest production was observed in isolate 68A-4 (H/G = 44.98 ± 9.66) and *Brevundimonas diminuta* 512B-6 (H/G = 23.36 ± 2.34). Antifungal assays revealed variable inhibitory effects on mycelial growth. The isolate *Serratia* sp. 19A-5 exhibited the strongest antifungal activity and showed no statistically significant difference compared to the reference strain *Bacillus subtilis* QST 713 in inhibiting *Penicillium olsonii* and *Fusarium oxysporum*. These results suggest that *Serratia* sp. 19A-5 represents a promising candidate for compost fortification with enhanced antifungal properties. The use of such beneficial bacteria as biological control agents represents a sustainable alternative to chemical pesticides, contributing to reduced environmental impact.

Keywords: plant growth-promoting bacteria, siderophores, biocontrol, phytopathogenic fungi, compost

INTRODUCTION

Composting is an exothermic process of biological oxidation, during which organic substrate is subjected to aerobic biodegradation under controlled conditions by microorganisms commonly present in the input materials **(Krstic *et al.*, 2019)**. Input raw materials provide nutrients and energy for primary decomposers, which are microorganisms, mainly bacteria and fungi **(Oshins *et al.*, 2022)**. Intensive microbial activity leads to a rapid increase in temperature during the bio-oxidative phase of the process, which starts at ambient temperatures and with a microbial community originating from the input raw materials **(Suárez-Estrella *et al.*, 2019)**. The composting process has four phases: mesophilic, thermophilic, cooling, and maturation **(Ho *et al.*, 2022)**. In the initial stages of composting, mesophilic bacteria predominate, represented by Gram-negative genera, particularly *Escherichia*, *Pseudomonas*, *Klebsiella*, *Aeromonas*, and *Alcaligenes*, and Gram-positive genera *Enterococcus* and *Bacillus*. These bacteria utilize readily available sugars, which is associated with their rapid reproduction and higher metabolic activity. When the temperature in the compost exceeds 40 °C, mesophilic bacteria are replaced by thermophilic species, dominated by the genus *Bacillus*. At temperatures above 55 °C, the number of non-spore-forming rod-shaped bacteria decreases, and the number of spore-forming bacteria increases. Bacterial species such as *Bacillus schlegelii*, *Thermus thermophilus*, and *Thermus aquaticus* are typical for compost temperatures of 65 °C and above **(Mehta *et al.*, 2014)**. During the cooling and ripening phases, bacteria such as *Pseudomonas, Bacillus, Flavobacterium* and *Cellulomonas predominate* **(Ho *et al.*, 2022)**. The composition of microbial communities' changes during the composting process, and the composting process itself is influenced by many factors, including the pH of the compost, the C/N ratio, moisture content, type of input substrate, oxygen availability, and composting technology **(Pezzola *et al.*, 2021)**.
Compost contains not only beneficial and useful microorganisms (i.e., those responsible for the composting process), but also those that are harmful to humans, animals, plants, or the environment. Plant pathogens are a common component of plant residues, but when household waste is composted, human pathogens such as *Salmonella* are not uncommon **(Fuchs, 2009)**. One of the key objectives of composting is the inactivation of harmful microorganisms during sanitization and the development of a beneficial microbial community. High temperature is important for the sanitization process **(Downer *et al.*, 2008)**, which interacts with moisture **(Fayolle *et al.*, 2006)**.

Plant diseases pose a significant threat to many agricultural and horticultural crops **(Suárez-Estrella *et al.*, 2019)**, and compost is considered a potential alternative for controlling soil pathogens **(Termorshuizen *et al.*, 2006)** and enhancing plant growth. According to a study by **Neher *et al.* (2022)**, compost naturally suppresses the pathogens *Pythium* and *Phytophthora*, which cause root rot in vegetables, fruits, woody ornamental plants, and forest trees, as well as *Fusarium oxysporum* and *Verticillium dahliae,* which cause diseases in cereals and grasses.
Since the properties of compost are controlled by mechanisms of microbial origin, phytopathogen control and plant growth are achieved thanks to the presence of certain plant growth promoting bacteria (PGPB) in the composting process of organic substrate **(Martínez-Cano *et al.*, 2021)**. PGPB have phytostimulating effects, interfere with biochemical cycles, actively participate in nutrient availability, and have biological control agent properties. The aim of this study was to isolate bacteria from composts and determine their potential biocontrol effect against phytopathogenic fungi. The findings will be of great importance in addressing the challenges faced by agricultural practice: improving soil and plant health, resulting in high-quality crops. Fortifying compost with bacteria exhibiting antifungal activity is another promising technique with suppressive activity for eliminating pathogens in both compost and soil.

MATERIAL AND METHODS

Collection and processing of compost samples

Between 2024 and 2025, five compost samples aged 3-4 months were collected from two composting facilities. Samples 1-3 and 5 were obtained from the Výčapy Opatovce industrial composting plant in Slovakia (48°24′33.34′′ N, 18°6′30.14′′ E), which employs aerobic windrow composting technology. This facility processes biodegradable municipal and green waste using layered stacking of crushed and homogenized material in windrows up to 3.0 m in height. Sample 4 was collected from a composting facility operated by Živá záhrada Leopoldov in Slovakia (48°26′51.8″ N, 17°46′36.3″ E), which processes green waste from municipal maintenance using aerobic composting.
After collection, samples were stored at 4 °C in a portable cooler and transported to the laboratory of the Institute of Biotechnology, Faculty of Biotechnology and Food Sciences, Slovak University of Agriculture in Nitra. Subsequently, samples were homogenized and prepared for further analyses.

Physical and chemical properties of compost

The moisture and dry matter content of the samples was determined according to **BS EN 13040**, while the combustible matter content according to **BS EN 13039**. The pH and electrical conductivity were measured potentiometrically using a pH meter (Hannah Instruments) in a compost-distilled water suspension (1:10, w/v). All analyses were performed in triplicates (Table 1).

Table 1 Determined physical and chemical parameters of composts (average ± standard deviation)

Compost number	Moisture [%]	Dry matter [%]	Combustible substances [%]	pH	Electrical conductivity [mS/cm]
1	29.22 ± 0.22	70.77 ± 0.22	61.45 ± 0.59	8.85 ± 0.01	2.08 ± 0.12
2	17.84 ± 1.24	82.16 ± 1.24	54.37 ± 2.22	8.43 ± 0.01	1.99 ± 0.28
3	22.03 ± 1.55	77.97 ± 1.55	48.63 ± 1.61	9.12 ± 0.20	1.68 ± 0.13
4	47.76 ± 2.42	52.24 ± 2.42	72.17 ± 1.44	9.53 ± 0.07	0.71 ± 0.05
5	48.50 ± 0.40	51.50 ± 0.40	71.09 ± 0.60	8.58 ± 0.14	0.90 ± 0.13

Isolation and characterization of bacteria in compost

Bacterial isolates were obtained using the plate dilution method. A 10 g sample was suspended in 90 mL of sterile 0.85% saline solution. After subsequent mixing of the sample on a laboratory shaker at 150 rpm, further dilutions of 10^{-2} to 10^{-8} were prepared. After inoculation of the suspension on PCA (Plate Count Agar; HiMedia Laboratories, India), incubation was performed at 30 ± 1°C for 72 ± 3 h. After that, only morphologically distinct colonies were isolated using the streak plate method on PCA to obtain monocultures, and the purity of the isolates was verified by Gram staining. From a collection of 38 bacterial isolates, 12 isolates were selected for antagonistic assays against fungal pathogens. The selection was based on a preliminary screening of plant growth-promoting traits, which is not presented in this study. Isolates representing different combinations of IAA (indole-3-acetic acid) production, phosphate solubilization, and cellulolytic activity were included, with preference given to isolates exhibiting multiple beneficial traits potentially associated with plant growth promotion and biocontrol activity. Biochemical characterization included catalase and oxidase tests (**Hafezi and Khamar, 2024**). The identification of bacterial isolates was carried out by MALDI-TOF MS (Bruker Daltonics, Munich, Germany, Maldi Biotyper) using 24-hour cultures of each strain according to **Hleba *et al*. (2017)**. One colony from each bacterial strain was deposited on a MALDI target plate by sterile toothpick and left to dry. After drying, 2 µL of matrix solution (saturated α-cyano-4-hydroxycinnamic acid, 50% acetonitrile, 2.5% trifluoroacetic acid) were added and allowed to co-crystallize with the sample. Spectra were analyzed using Flex Control 3.4 software (Bruker Daltonics, Inc., Billerica, MA, USA) and MALDI BiotyperOC version 3.1 (Bruker Daltonics, Bremen, Germany).

Testing the ability of bacterial isolates to produce siderophores

Siderophore production was assessed using the Chrome Azurol S (CAS) assay according to **Schwyn and Neilands (1987)** , with hexadecyltrimethylammonium bromide (HDTMA). The CAS/HDTMA complex binds strongly to trivalent iron (Fe^{3+}), producing a blue colour. The production of siderophores by bacteria removes iron from the complex and changes the colour from blue to orange **(Louden *et al*., 2011)**. A Haloes Caliper (IUL Instruments) was used to measure the diameter of the colony and the halo zone (mm). The ratio of the halo zone area to the colony area (H/G) was calculated for each bacterial isolate. If H/G > 1, the halo zone is larger than the colony itself, indicating siderophore production. According to **Dhul *et al*. (1998)**, bacterial isolates were classified as follows: H/G > 7 = high siderophore production; 3.6 < H/G < 5.0 = medium siderophore production; 1.7 < H/G < 3.2 = low siderophore production.

Testing the suppressive activity of bacterial isolates against selected fungal pathogens

The agar disc diffusion method was used to test the suppressive activity of bacterial isolates against pathogens, in which the inhibition of the growth of one microorganism against another was tested **(Balouiri *et al*., 2016).** The antifungal activity of selected bacterial isolates was tested against phytopathogenic fungi of the species *Botrytis cinerea*, *Fusarium oxysporum*, *Penicillium olsonii*, and *Alternaria alternata*, originating from the collection of the Institute of Biotechnology, FBFS SUA in Nitra. Suspensions with a density of 0.5 MacFarland turbidity standard ($1.5x10^8$ CFU/mL) were prepared from the bacterial isolates grown on PCA agar (30 ± 1°C, 24 h) and inoculated in a volume of 100 µL onto the surface of MEA agar (Malt extract agar; HiMedia Laboratories, India). Mycelial plugs of fungi (5 mm diameter) were cut out from the edges of an actively growing colony and placed mycelial side down on the agar, at the center of the assay plates. A plate of MEA agar without bacterial suspension was used as a control. The reference strain of the bacterium *Bacillus subtilis* QST 713, with confirmed antifungal activity, was used as a control strain for comparison with the tested isolates. *Bacillus subtilis* QST 713 the basis of the biological product SERENADE®, which is characterized by high efficacy in biological plant protection **(Reiss and Jørgensen, 2017)**. SERENADE® is used as a broad-spectrum fungicide. Incubation took place at a temperature of 25 ± 1°C for 7 days. The percentage of inhibition (%) was calculated using the equation published by **Fernando and Pierson (1999)**: Growth inhibition (%) = (R1 – R2)/R1x100, where R1 is radius of mycelium growth on the control plate and R2 is radius of mycelium growth on the experimental plate.

Statistical evaluation

The results of the analyses are presented as an average of biological three replicates. GraphPad Prism version 11 (GraphPad Software, San Diego, CA, USA) was used for the statistical evaluation of the results of the suppressive activity of bacterial isolates against selected fungal pathogens. To determine statistically significant differences in mycelial growth inhibition between the reference strain *Bacillus subtilis* QST 713 and other bacterial isolates, one-way analysis of variance was used (ANOVA). Dunnett's test was used to test statistically significant differences between means.

RESULTS AND DISCUSSION

Characterization of bacterial isolates

Composting is an effective method of recycling organic waste that produces a multipurpose product (compost), which, thanks to its cost-effectiveness and environmental friendliness, is an indispensable component of sustainable agriculture (**Onwosi *et al*., 2020**). Compost provides a valuable source of nutrients and microorganisms that generally contribute to improving soil quality and health, and thus the crops grown in it. The presence of bacteria in compost has a positive effect on stimulating plant growth and protecting plants against pathogens, which are the main cause of reduced crop yields and lead to significant economic losses **(Aguilar-Paredes *et al*., 2023)**.

Table 2 Morphological and biochemical characteristics of bacterial strain, and results of MALDI-TOF testing

Strain	Maldi Best Match	MALDI Score*	Morphological characteristics	Spore formation	Oxidase test	Catalase test
19A-5	*Serratia rubidaea*	1.843	Gram-negative rod-shaped	-	-	+
115A-8	*Bacillus amyloliquefaciens*	1.399	Gram-positive rod-shaped	+	-	+
28A-4	*Enterobacter hormaechei*	2.033	Gram-negative rod-shaped	-	-	+
59B-5	*Stenotrophomonas acidaminiphila*	1.503	Gram-negative rod-shaped	-	-	+
510A-5	*Staphylococcus hominis*	2.096	Gram-positive cocci	-	-	+
512B-6	*Brevundimonas diminuta*	2.018	Gram-negative rod-shaped	-	+	+
68A-4	*Chryseobacterium aquifrigidense*	1.637	Gram-negative rod-shaped	-	+	+
68B-4	*Bacillus megaterium*	1.987	Gram-positive rod-shaped	+	-	+
68C-4	*Bacillus mojavensis*	1.885	Gram-positive rod-shaped	+	-	+
78B-4	*Sphingobium chlorophenolicum*	1.441	Gram-negative rod-shaped	-	+	+
78C-4	*Pseudomonas brassicacearum*	1.903	Gram-negative rod-shaped	-	+	+
79B-5	*Pseudarthrobacter oxydans*	1.644	Gram-positive pleomorphic	-	-	+

*****MALDI scores of 2.000-2.299 indicate secure genus identification and probable species identification; 1.700-1.999 indicate probable genus identification; <1.7 indicate no reliable MALDI identification

The use of compost in biological plant control as a preventive measure against various diseases is confirmed by numerous studies **Hoitink and Boehm (1999)**, **Termorshuizen *et al*. (2006), Mehta *et al*. (2014), Zouari *et al*. (2020)**.
From the analyzed compost samples, 38 bacterial isolates were obtained from morphologically distinct bacterial colonies grown on PCA agar; of these, 12 isolates demonstrated significant plant-growth-promoting activity and were subjected to further characterization and testing. Based on morphological characteristics, rod-shaped Gram-negative strains predominated (7), lacking the ability to form endospores and testing positive for catalase (Table 2). Four isolates belonged to Gram-positive bacteria, and three of them were capable of forming endospores.

Production of siderophores by bacterial isolates

Siderophores are organic molecules with low molecular weight and high affinity for iron. Siderophores bind insoluble Fe^{3+} ions, which are subsequently reduced to the usable form Fe^{2+}. The ability of microorganisms to produce siderophores is crucial for them in iron-deficient soils, which they utilize for their growth and metabolism **(Lipková *et al*., 2021)**. Siderophores play a role in promoting plant growth by mediating iron uptake for the plant and simultaneously entering into a competitive relationship for iron with phytopathogenic fungi **(Neilands, 1995)**. The detection of siderophores using chrom azurol S (CAS) agar plates is based on the ability of siderophores to act as chelators with varying affinities for iron. The presence of this iron chelator is indicated by the decolorization of the blue-coloured ferric CAS complex, resulting in an orange halo around the colonies on CAS plates. Table 3 shows siderophore production by bacterial strains on CAS agar plates. Of the 12 isolates tested, we confirmed the ability to produce siderophores in 8 isolates. Siderophore production was "corrected" for growth by dividing the area of the halo zone by the colony area (H/G, Table 3). The highest siderophore production was exhibited by the isolate. 68A-4 isolate with an H/G ratio of 44.98 ± 9.66, which, according to **Dhul *et al*. (1998)**, classifies it among isolates with high siderophore production. This category would also include the isolates *Brevundimonas diminuta* 512B-6 with an H/G of 23.36 ± 2.34, isolate, *Serratia* sp. 19A-5 with an H/G of 9.54 ± 0.52, and isolate *Enterobacter hormaechei* 28A-4 with an H/G of 7.81 ± 0.71. Three isolates exhibited moderate siderophore production, and one isolate exhibited lower siderophore production. Low production, i.e., low ability to capture Fe, indicates either the production of a small amount of siderophores or the production of siderophores with low affinity. We hypothesize that the significant siderophore production observed in the isolates 68A-4 and *Brevundimonas diminuta* 512B-6 is associated with their origin from alkaline composts (pH 9.53 and 9.12, respectively), as siderophore production has been reported to increase in alkaline environments due to reduced iron solubility (**Kumar *et al*., 2017**). The reference strain *Bacillus subtilis* QST 713 exhibited siderophore production of 5.75 ± 0.76.

Table 3 Siderophore production by bacterial strains (mean ± standard deviation)

Strain	Siderophore production	Colony diameter (mm) [G]	Halo zone + colony diameter (mm) [H]	Growth to halo zone ratio [H/G]
19A-5	+	4.25 ± 0.25	13.13 ± 1.13	9.54 ± 0.52
115A-8	+	9.55 ± 0.61	17.34 ± 0.68	3.30 ± 0.16
28A-4	+	4.41 ± 0.29	12.30 ± 0.35	7.81 ± 0.71
59B-5	-	2.50 ± 0.13	Nd	Nd
510A-5	+	7.06 ± 0.27	15.15 ± 0.97	4.62 ± 0.64
512B-6	+	3.61 ± 0.28	17.40 ± 0.45	23.36 ± 2.34
68A-4	+	5.88 ± 1.00	38.90 ± 3.42	44.98 ± 9.66
68B-4	-	5.00 ± 0.17	Nd	Nd
68C-4	-	3.00 ± 0.26	Nd	Nd
78B-4	+	4.55 ± 0.20	11.05 ± 0.79	5.98 ± 1.33
78C-4	+	9.40 ± 0.46	22.91 ± 1.38	5.99 ± 1.05
79B-5	-	2.00 ± 0.26	Nd	Nd
***Bacillus subtillis* QST 713**	+	7.33 ± 0.40	17.56 ± 1.25	5.75 ± 0.76

G = Growth expressed as colony diameter; H=Siderophore production expressed as halo zone diameter; H/G – Halo zone area $(0.5\ H)^2$ divided by growth area $(0.5\ G)^2$, nd= Not detected

Antifungal activity of bacterial isolates

The results of our experiment are consistent with the finding by **Fuchs (2009**) that applying compost to the soil not only increases soil microbial activity but also makes the crops more resistant to pathogens. In the antifungal activity test, 12 bacterial isolates were tested against the microscopic filamentous fungi *Botrytis cinerea*, *Penicillium olsonii*, *Fusarium oxysporum*, and *Alternaria alternata* (Figure 1), where differences in the ability to inhibit mycelial growth were demonstrated. *Bacillus subtilis* QST 713 was used as the reference bacterial strain, which demonstrated 100% inhibition of mycelial growth for all tested fungi. This strain forms the basis of the biological product SERENADE®, which is characterized by high efficacy in biological plant protection. Its mechanism of action involves antifungal and antibacterial activity, induced systemic plant resistance (ISR), and promotion of plant growth. An advantage of its use is its harmlessness to the environment and other non-target organisms such as pollinators, other beneficial insects, or humans **(Reiss and Jørgensen, 2017)**. Since not all bacterial isolates could inhibit the growth of selected fungi (Table 4), only those isolates in which we confirmed this ability were selected for statistical comparison with the reference strain. The lowest number of isolates (3) capable of antifungal activity was confirmed against the microscopic fungus *Penicillium olsonii* (Figure 1b). The bacterium *Serratia* sp. 19A-5 exhibited the highest antifungal activity (79.6 ± 0.1%), which was significantly comparable to the reference strain *B. subtilis* QST 713. Four isolates exhibited antifungal activity against the fungus *Botrytis cinerea* (Figure 1a), and nine isolates against the fungus *Alternaria alternata* (Figure 1c). However, none of the isolates exhibited antifungal activity against the fungi *Botrytis cinerea* and *Alternaria alternata* that was significantly comparable to the reference strain *B. subtilis* QST 713. Against the fungus *Fusarium oxysporum*, all 12 isolates exhibited antifungal activity ranging from 13.2 ± 0.00 to 84.3 ± 5.16%, and for three isolates—*Serratia* sp. 19A-5, 115A-8, and 59B-5, antifungal activity comparable to that of the reference strain *B. subtilis* QST 713 was significantly confirmed. However, no significant production of siderophores was confirmed for these isolates (Table 3), suggesting that these isolates utilize mechanisms other than iron competition to suppress pathogens (production antibiotic or volatile compounds), or that there was sufficient iron in the compost. The production of siderophores is generally not essential for biological control potential, as confirmed by the study by **Thomashow and Weller (1990)**, in which the production of the antibiotic phenazine-1-carboxylic acid was crucial for the suppression of the *Pseudomonas fluorescens* strain 2-79. Similarly, the siderophore-nonproducing *Paenibacillus pasadenensis* strain R-16 was effective against *Botrytis cinerea* through the action of volatile compounds such as farnesol **(Passera *et al*., 2017)**.
Our bacterial isolate *Serratia* sp. 19A-5 exhibited antifungal activity against two microscopic fungi, *Fusarium oxysporum* (84.3±5.16%) and *Penicillium olsonii* (79.6±0.0%), which was significantly comparable to the reference strain *B. subtilis* QST 713. Similar results were confirmed by **Someya *et al*. (2000)** under *in vitro* conditions, where the action of *Serratia marcescens* strain B2 inhibited the growth of *Fusarium oxysporum* f sp. *Cyclaminis* by 70%. The study by **Trejo-López *et al*. (2022)** confirms the antifungal activity of *Serratia marcescens* and *S. nematodiphila* against the growth of *Alternaria alternata* mycelium as well. Our isolate *Serratia* sp. 19A-5 also inhibited the growth of the fungus *Alternaria alternata*, but the growth inhibition was not significantly comparable to that of the reference strain *Bacillus subtilis* QST 713. *Serratia* sp. is one of the most efficient bacteria known to produce metabolites and compete with fungal phytopathogens in the soil. The metabolites include antibiotics, siderophores, HCN, cell wall-degrading enzymes, quorum-sensing molecules, and N-acyl homoserine lactones (AHLs) **(Ryu *et al*., 2013; Kshetri *et al*., 2019)**.
Other isolates exhibiting significant antifungal activity against *Fusarium oxysporum* comparable to the reference strain included isolates 115 A-8 and 59 B-5. For these isolates, MALDI identification was not accurate, and further identification using molecular methods will be necessary. Although the literature reports antifungal activity for these species identified by MALDI protein spectroscopy. **Li *et al*. (2024)** confirmed antifungal activity against fungal pathogens belonging to the genus *Fusarium* in the bacterial isolate *Bacillus amyloliquefaciens* BA-4, and **Rojas-Solís *et al*. (2018)** confirmed the excellent

antifungal activity of the endophytic strain *Stenotrophomonas acidaminiphila* SR71 against *Botrytis cinerea* through the emission of volatile organic compounds (VOCs).

Table 4 Growth inhibition (%) bacterial isolates againts fungal pathogens (mean ± standard deviation)

Strain	*Botrytis cinerea*	*Penicillium olsonii*	*Alternaria alternata*	*Fusarium oxysporum*
***Bacillus subtillis* QST 713**	100.0 ± 0.00	100.0 ± 0.00	100.0 ± 0.00	100.0 ± 0.00
19A-5	81.3 ± 3.54	79.6 ± 0.00	88.0 ± 0.00	84.3 ± 5.16
115A-8	40.6 ± 0.92	38.9 ± 10.47	48.9 ± 3.11	77.1 ± 2.55
28A-4	0.0 ± 0.00	0.0 ± 0.00	54.3 ± 2.26	62.3 ± 6.15
59B-5	0.0 ± 0.00	0.0 ± 0.00	9.8 ± 0.49	78.3 ± 8.20
510A-5	0.0 ± 0.00	0.0 ± 0.00	30.9 ± 6.93	21.3 ± 2.55
512B-6	0.0 ± 0.00	0.0 ± 0.00	13.0 ± 2.26	29.0 ± 5.59
68A-4	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	13.2 ± 0.00
68B-4	0.0 ± 0.00	0.0 ± 0.00	18.5 ± 3.11	33.3 ± 16.40
68C-4	13.1 ± 6.15	0.0 ± 0.00	23.9 ± 3.89	14.1 ± 0.71
78B-4	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	35.1 ± 14.92
78C-4	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	34.3 ± 13.86
79B-5	0.0 ± 0.00	0.0 ± 0.00	9.8 ± 4.60	41.6 ± 6.65

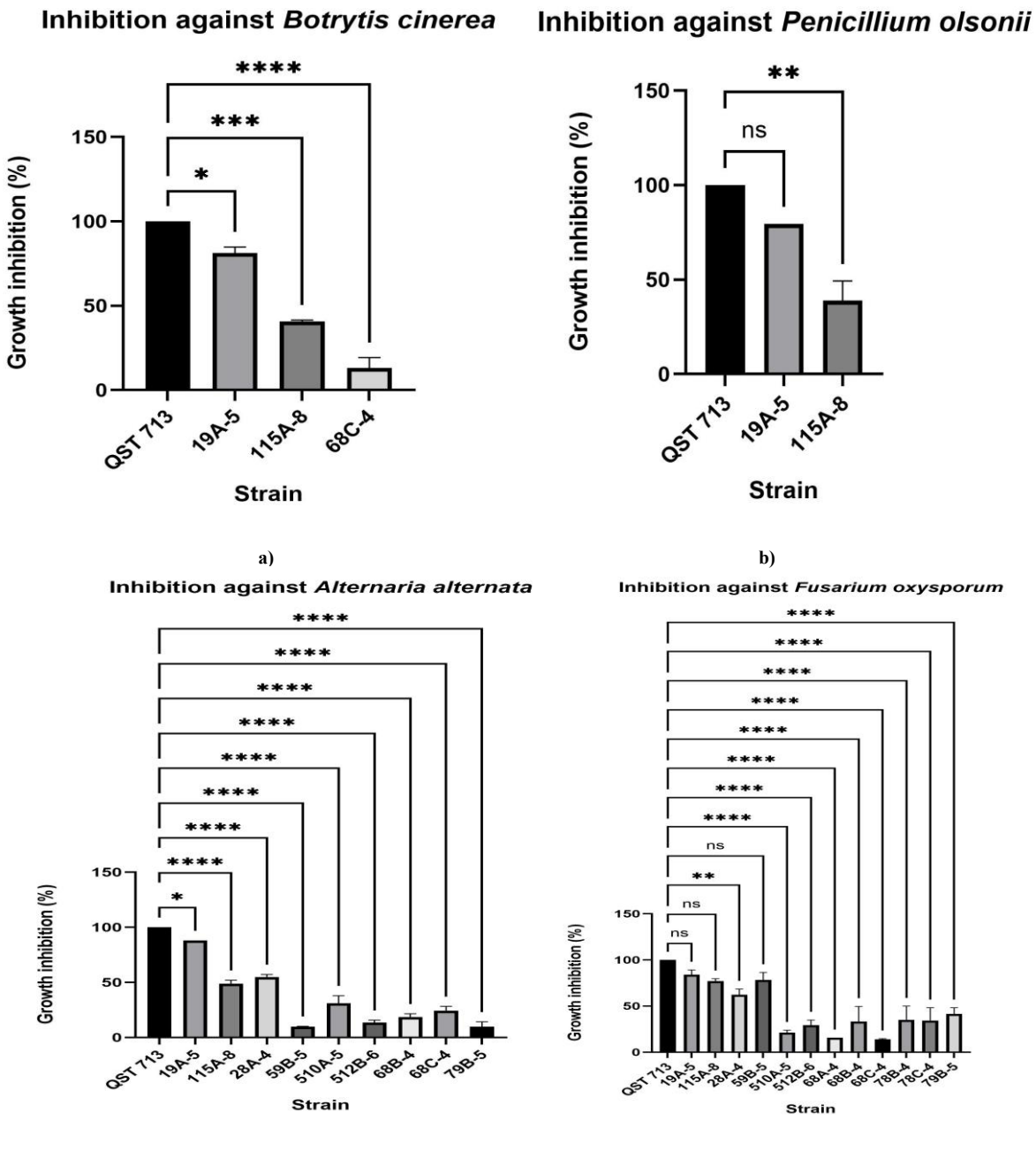

Figure 1 Percentage inhibition of mycelium growth [%] of fungi by bacterial strains compared to the reference strain *Bacillus subtilis* QST 713; ns – not significant; * p<0.05; ** p<0.01; *** p<0.001; **** p<0.0001

CONCLUSION

The results of this screening study confirm that compost represents a valuable source of bacteria with significant biocontrol potential against phytopathogenic fungi capable of inhibiting mycelial growth under *in vitro* conditions. Among the tested isolates, bacterium *Serratia* sp. 19A-5 demonstrated the strongest antifungal activity, particularly against *Penicillium olsonii* and *Fusarium oxysporum*, with effects comparable to the reference strain *Bacillus subtilis* QST 713. These findings suggest that bacterium *Serratia* sp. 19A-5 could be a suitable candidate for the development of compost-based biofortification strategies aimed at enhancing antifungal properties. Its application in soil could contribute to improved plant health and increased resistance to fungal pathogens. Research into new biological control agents is a long and complicated process, beginning with the isolation and identification of new candidates exhibiting antifungal activity and ending with field trials. Future research should focus on molecular identification and phylogenetic analysis of this bacterium, as well as on elucidating the mechanisms underlying its biocontrol activity in *in vivo* conditions and optimizing its practical application under field conditions.

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