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SIDEROPHORE PRODUCTION IN PHOSPHATE-SOLUBILIZING *PENICILLIUM* SPP.

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Abstract. Siderophores are essential compounds that contribute to iron availability and play a broader role in nutrient utilization, including phosphate solubilization. In this study, siderophore production by phosphate-solubilizing *Penicillium* spp. was investigated, and the relationship between siderophore production and phosphate-solubilizing activity was evaluated. The siderophore activity varied from 3.2 ± 1.0 (*P. vulpinum* 2878) to 57.4 ± 3.8 (*P. funiculosum* 16783). The *Penicillium funiculosum* strains were characterized as high siderophore producers and demonstrated potential for further investigation.

Keywords: siderophores, *Penicillium*, phosphate-solubilization, plant-growth promoting microorganisms, sustainable agriculture.

Introduction. Siderophores are low-molecular-weight compounds produced in various organisms that facilitate iron acquisition through Fe^{3+} chelation and increase its availability for uptake (Swayambhu, 2021). However, the role of siderophores extends beyond iron acquisition for the nutritional needs of the producer. Some siderophores exhibit antimicrobial activity and may contribute to microbial competition as they limit iron availability to phytopathogenic microorganisms (Gu, 2020). Another, less investigated role of siderophores is their involvement in phosphate solubilization, potentially enhancing the availability of phosphorus for plants (Ashash, 2025). Therefore, this study aimed to investigate siderophore production among phosphate-solubilizing strains of the genus *Penicillium*.

Materials and methods. The study included 106 strains representing 37 species of the genus *Penicillium*. Siderophore production was quantitatively evaluated in 7-day culture filtrates obtained from cultures grown in NBRIP medium. Phosphate-solubilizing activity of the experimental strains had previously been investigated using the same culture samples. Siderophore production was assessed using the Chrome Azurol S (CAS) assay according to the following formula:

$$\text{Siderophore activity, \%} = \frac{A_r - A_s}{A_r} \times 100,$$

where A_r is the absorbance of the reference sample (CAS reagent with uninoculated medium) and A_s is the absorbance of the tested sample. Absorbance was measured at 620 nm (Schwyn, 1987). All experiments were performed in triplicate. Statistical analyses were conducted at a significance level of $p \leq 0.05$ using STATISTICA 7. Data visualization was performed using OriginLab 2026.

Results. All experimental strains demonstrated the ability to produce hydroxamate-type siderophores, as indicated by a color change of the CAS reagent from blue to violet or pink, depending on the amount of siderophore produced. Siderophore activity varied among the tested strains, with 2.8 %, 16.0 %, 28.3 %, 26.4 %, 25.5 % and 0.9 % of strains exhibiting activity levels of $x - 0-10$ %, $10-20$ %, $20-30$ %, $30-40$ %, $40-50$ %, and $50-60$ %, respectively. Seven strains of *P. funiculosum*, along with one strain each of *P. hirsutum*, *P. lanosum*, and *P. rubrum*, exhibited the highest siderophore activity. The significant positive correlation ($r = 0.3$) between intensity of phosphate-solubilization and siderophore production was identified.

Conclusions. The study demonstrated the ability of phosphate-solubilizing *Penicillium* strains to produce hydroxamate-type siderophores and revealed significant correlations between siderophore production and phosphate-solubilizing activity. A pronounced strain-specific pattern of siderophore production was also observed. The experimental strains were indicated as promising for further studies related to phosphate solubilization and siderophore production and for potential application in agriculture.

References:

1. Ahash, S., Manikandan, K., Sivasankari Devi, T., Elamathi, S., Maragatham, S., & Subrahmaniyan, K. (2025). Phosphate-solubilizing microorganisms for sustainable phosphorus management in rice. *Rhizosphere*, 34, 101096. <https://doi.org/10.1016/j.rhisph.2025.101096>
2. Gu, S., Wei, Z., Shao, Z., Friman, V. P., Cao, K., Yang, T., Kramer, J., Wang, X., Li, M., Mei, X., Xu, Y., Shen, Q., Kümmerli, R., & Jousset, A. (2020). Competition for iron drives phytopathogen control by natural rhizosphere microbiomes. *Nature microbiology*, 5(8), 1002–1010. <https://doi.org/10.1038/s41564-020-0719-8>
3. Schwyn, B., & Neilands, J. B. (1987). Universal chemical assay for the detection and determination of siderophores. *Analytical biochemistry*, 160(1), 47–56. [https://doi.org/10.1016/0003-2697\(87\)90612-9](https://doi.org/10.1016/0003-2697(87)90612-9)
4. Swayambhu, G., Bruno, M., Gulick, A. M., & Pfeifer, B. A. (2021). Siderophore natural products as pharmaceutical agents. *Current opinion in biotechnology*, 69, 242–251. <https://doi.org/10.1016/j.copbio.2021.01.021>

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PRODUCTION OF AUXIN-LIKE COMPOUNDS AND SIDEROPHORES BY *OCHROBACTRUM RHIZOSPHAERAE* IMV B-7956 UNDER THE INFLUENCE OF NaCl

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Abstract. The ability of *Ochrobactrum rhizosphaerae* IMV B-7956 bacteria to produce auxin-like compounds and siderophores at various NaCl concentrations was investigated. The bacteria, isolated from filtrates of the Lviv municipal solid waste landfill, were cultured in LB liquid medium containing NaCl concentrations of 0.5, 2.5, 4.5, and 6.5 % for 5 days. On days 3, 4, and 5 biomass accumulation and the content of auxin-like compounds and siderophores in the culture medium were determined. Auxin-like compounds and siderophores were determined using a spectrophotometric method, while biomass was determined by weighing. It was found that the NaCl concentration affected both bacterial growth and the production of the studied metabolites; the highest biomass accumulation was observed at 4.5 % NaCl, whereas the addition of 6.5 % NaCl significantly inhibited culture growth. The highest production of siderophores was recorded at 4.5 % NaCl on days 4 and 5 of cultivation, whereas the highest levels of auxin-like compounds were predominantly observed at lower NaCl concentrations. The results obtained confirm the promise of further study of the biotechnological potential of *O. rhizosphaerae* IMV B-7956 bacteria.

Keywords: plant growth-promoting bacteria, phytohormones, siderophores, halotolerance.

Introduction. Auxins, particularly indole-3-acetic acid (IAA), play a key role in plant growth and development by the regulation of cell division, elongation, and root system