**Molecular insight into key eco-physiological process in bioremediating and plant-growth-promoting bacteria**

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**References for Table 1:**

Chauhan, R., Awasthi, S., Indoliya, Y., Chauhan, A. S., Mishra, S., Agrawal, L., ... & Tripathi, R. D. (2020). Transcriptome and proteome analyses reveal selenium mediated amelioration of arsenic toxicity in rice (Oryza sativa L.). Journal of hazardous materials, 390, 122122. doi: 10.1016/j.jhazmat.2020.122122

Armendariz, A. L., Talano, M. A., Travaglia, C., Reinoso, H., Oller, A. L. W., & Agostini, E. (2016). Arsenic toxicity in soybean seedlings and their attenuation mechanisms. Plant Physiology and Biochemistry, 98, 119-127. doi:10.1016/j.plaphy.2015.11.021

Yoon, Y., Lee, W. M., & An, Y. J. (2015). Phytotoxicity of arsenic compounds on crop plant seedlings. Environmental Science and Pollution Research, 22(14), 11047-11056. doi: 10.1007/s11356-015-4317-x

Ozfidan-Konakci, C., Yildiztugay, E., Elbasan, F., Kucukoduk, M., & Turkan, I. (2020). Hydrogen sulfide (H2S) and nitric oxide (NO) alleviate cobalt toxicity in wheat (Triticum aestivum L.) by modulating photosynthesis, chloroplastic redox and antioxidant capacity. Journal of hazardous materials, 388, 122061. doi: 10.1016/j.jhazmat.2020.122061

Li, H. F., Gray, C., Mico, C., Zhao, F. J., & McGrath, S. P. (2009). Phytotoxicity and bioavailability of cobalt to plants in a range of soils. Chemosphere, 75(7), 979-986. doi: 10.1016/j.chemosphere.2008.12.068

Xu, D., Chen, Z., Sun, K., Yan, D., Kang, M., & Zhao, Y. (2013). Effect of cadmium on the physiological parameters and the subcellular cadmium localization in the potato (Solanum tuberosum L.). Ecotoxicology and environmental safety, 97, 147-153. Doi: 10.1016/j.ecoenv.2013.07.021

Chatterjee, J., & Chatterjee, C. (2000). Phytotoxicity of cobalt, chromium and copper in cauliflower. Environmental pollution, 109(1), 69-74. doi: 10.1016/S0269-7491(99)00238-9

Pandey, V., Dixit, V., & Shyam, R. (2009). Chromium effect on ROS generation and detoxification in pea (Pisum sativum) leaf chloroplasts. Protoplasma, 236(1-4), 85-95. doi: 10.1007/s00709-009-0061-8

Sundaramoorthy, P., Chidambaram, A., Ganesh, K. S., Unnikannan, P., & Baskaran, L. (2010). Chromium stress in paddy:(i) nutrient status of paddy under chromium stress;(ii) phytoremediation of chromium by aquatic and terrestrial weeds. Comptes rendus biologies, 333(8), 597-607. doi: 10.1016/j.crvi.2010.03.002

Erturk, F. A., Agar, G., Arslan, E., Nardemir, G., & Sahin, Z. (2014). Determination of genomic instability and DNA methylation effects of Cr on maize (Zea mays L.) using RAPD and CRED-RA analysis. Acta Physiologiae Plantarum, 36(6), 1529-1537. doi:10.1007/s11738-014-1529-5

Akanbi-Gada, M. A., Ogunkunle, C. O., Vishwakarma, V., Viswanathan, K., & Fatoba, P. O. (2019). Phytotoxicity of nano-zinc oxide to tomato plant (Solanum lycopersicum L.): Zn uptake, stress enzymes response and influence on non-enzymatic antioxidants in fruits. Environmental Technology & Innovation, 14, 100325. doi: 10.1016/j.eti.2019.100325

Mossa, A. W., Young, S. D., & Crout, N. M. (2020). Zinc uptake and phyto-toxicity: Comparing intensity-and capacity-based drivers. Science of the Total Environment, 699, 134314. doi: 10.1016/j.scitotenv.2019.134314

Sagardoy, R. U. T. H., Morales, F. E. R. M. Í. N., López‐Millán, A. F., Abadía, A. N. U. N. C. I. A. C. I. Ó. N., & Abadía, J. A. V. I. E. R. (2009). Effects of zinc toxicity on sugar beet (Beta vulgaris L.) plants grown in hydroponics. Plant Biology, 11(3), 339-350. doi: 10.1111/j.1438-8677.2008.00153.x

Shabnam, I., & Seema, M. (2011). Phytotoxicity of nickel and its accumulation in tissues of three Vigna species at their early growth stages. Journal of Applied Botany and Food Quality, 84(2), 223-228. doi:

Nazir, H., Asghar, H. N., Zahir, Z. A., Akhtar, M. J., & Saleem, M. (2016). Judicious use of kinetin to improve growth and yield of rice in nickel contaminated soil. International journal of phytoremediation, 18(7), 651-655. doi: 10.1080/15226514.2015.1094444

Nie, J., Pan, Y., Shi, J., Guo, Y., Yan, Z., Duan, X., & Xu, M. (2015). A comparative study on the uptake and toxicity of nickel added in the form of different salts to maize seedlings. International journal of environmental research and public health, 12(12), 15075-15087. doi: 10.3390/ijerph121214972

Saleem, M. H., Fahad, S., Khan, S. U., Din, M., Ullah, A., Sabagh, A. E., ... & Liu, L. (2020). Copper-induced oxidative stress, initiation of antioxidants and phytoremediation potential of flax (Linum usitatissimum L.) seedlings grown under the mixing of two different soils of China. Environmental Science and Pollution Research, 27(5), 5211-5221. doi: 10.1007/s11356-019-07264-7

Xu, J., Yang, L., Wang, Z., Dong, G., Huang, J., & Wang, Y. (2006). Toxicity of copper on rice growth and accumulation of copper in rice grain in copper contaminated soil. Chemosphere, 62(4), 602-607. doi: 10.1016/j.chemosphere.2005.05.050

Khatun, S., Ali, M. B., Hahn, E. J., & Paek, K. Y. (2008). Copper toxicity in Withania somnifera: Growth and antioxidant enzymes responses of in vitro grown plants. Environmental and experimental botany, 64(3), 279-285. doi: 10.1016/j.envexpbot.2008.02.004

Sądej, W., Żołnowski, A. C., Ciećko, Z., Grzybowski, Ł., & Szostek, R. (2019). Evaluation of the impact of soil contamination with mercury and application of soil amendments on the yield and chemical composition of Avena sativa L. Journal of Environmental Science and Health, Part A, 55(1), 82-96.doi: 10.1080/10934529.2019.1667671

Sahu, G. K., Upadhyay, S., & Sahoo, B. B. (2012). Mercury induced phytotoxicity and oxidative stress in wheat (Triticum aestivum L.) plants. Physiology and Molecular Biology of Plants, 18(1), 21-31. doi: 10.1007/s12298-011-0090-6

Shiyab, S., Chen, J., Han, F. X., Monts, D. L., Matta, F. B., Gu, M., & Su, Y. (2009). Phytotoxicity of mercury in Indian mustard (Brassica juncea L.). Ecotoxicology and Environmental Safety, 72(2), 619-625. doi: 10.1016/j.ecoenv.2008.06.002

Akinci, I. E., Akinci, S., & Yilmaz, K. (2010). Response of tomato (Solanum lycopersicum L.) to lead toxicity: Growth, element uptake, chlorophyll and water content. Afr J Agric Res, 5(6), 416-423. doi: 10.5897/AJAR10.016

Chatterjee, C., Dube, B. K., Sinha, P., & Srivastava, P. (2004). Detrimental effects of lead phytotoxicity on growth, yield, and metabolism of rice. Communications in soil science and plant analysis, 35(1-2), 255-265. doi: 10.1081/CSS-120027648

Lamhamdi, M., Bakrim, A., Aarab, A., Lafont, R., & Sayah, F. (2011). Lead phytotoxicity on wheat (Triticum aestivum L.) seed germination and seedlings growth. Comptes rendus biologies, 334(2), 118-126. doi: 10.1016/j.crvi.2010.12.006

Sager, S. M. A., Wijaya, L., Alyemeni, M. N., Hatamleh, A. A., & Ahmad, P. (2020). Impact of different cadmium concentrations on two pisum sativum l. genotypes. Pak. J. Bot, 52(3), 821-829. doi: 10.30848/PJB2020-3(10)

Srivastava, V., Sarkar, A., Singh, S., Singh, P., de Araujo, A. S., & Singh, R. P. (2017). Agroecological responses of heavy metal pollution with special emphasis on soil health and plant performances. *Frontiers in Environmental Science*, *5*, 64.

Wu, J., Guo, J., Hu, Y., & Gong, H. (2015). Distinct physiological responses of tomato and cucumber plants in silicon-mediated alleviation of cadmium stress. Frontiers in plant science, 6, 453. doi: 10.3389/fpls.2015.00453

Dias, M. C., Monteiro, C., Moutinho-Pereira, J., Correia, C., Gonçalves, B., & Santos, C. (2013). Cadmium toxicity affects photosynthesis and plant growth at different levels. Acta physiologiae plantarum, 35(4), 1281-1289. doi: 10.1007/s11738-012-1167-8

Shabnam, I., & Seema, M. (2011). Phytotoxicity of nickel and its accumulation in tissues of three Vigna species at their early growth stages. Journal of Applied Botany and Food Quality, 84(2), 223-228.

Edition, F. (2011). Guidelines for drinking-water quality. WHO chronicle, 38(4), 104-108.

Jomova, K., Jenisova, Z., Feszterova, M., Baros, S., Liska, J., Hudecova, D., ... & Valko, M. (2011). Arsenic: toxicity, oxidative stress and human disease. Journal of Applied Toxicology, 31(2), 95-107. doi: 10.1002/jat.1649

Zahir, F., Rizwi, S. J., Haq, S. K., & Khan, R. H. (2005). Low dose mercury toxicity and human health. Environmental toxicology and pharmacology, 20(2), 351-360. doi: 10.1016/j.etap.2005.03.007

Sun, H., Brocato, J., & Costa, M. (2015). Oral chromium exposure and toxicity. Current environmental health reports, 2(3), 295-303. doi: 10.1007/s40572-015-0054-z

Martelli, A., Rousselet, E., Dycke, C., Bouron, A., & Moulis, J. M. (2006). Cadmium toxicity in animal cells by interference with essential metals. Biochimie, 88(11), 1807-1814. doi: :10.1016/j.biochi.2006.05.013

Gillis, B. S., Arbieva, Z., & Gavin, I. M. (2012). Analysis of lead toxicity in human cells. BMC genomics, 13(1), 1-12. doi: 10.1186/1471-2164-13-344

Uriu-Adams, J. Y., & Keen, C. L. (2005). Copper, oxidative stress, and human health. Molecular aspects of medicine, 26(4-5), 268-298. doi: 10.1016/j.mam.2005.07.015

Leyssens, L., Vinck, B., Van Der Straeten, C., Wuyts, F., & Maes, L. (2017). Cobalt toxicity in humans—A review of the potential sources and systemic health effects. Toxicology, 387, 43-56. doi: 10.1016/j.tox.2017.05.015

Plum, L. M., Rink, L., & Haase, H. (2010). The essential toxin: impact of zinc on human health. International journal of environmental research and public health, 7(4), 1342-1365. doi: 10.3390/ijerph7041342

Denkhaus, E., & Salnikow, K. (2002). Nickel essentiality, toxicity, and carcinogenicity. Critical reviews in oncology/hematology, 42(1), 35-56. doi: 10.1016/S1040-8428(01)00214-1

**Reference list for Table-2**

Amin, A., & Latif, Z. (2016). Screening of mercury‐resistant and indole‐3‐acetic acid producing bacterial‐consortium for growth promotion of *Cicer arietinum* L. *Journal of basic microbiology*, *57*(3), 204-217. doi: [10.1002/jobm.201600352](https://doi.org/10.1002/jobm.201600352)

Arif, M.S., Yasmeen, T., Shahzad, S.M., Riaz, M., Rizwan, M., Iqbal, S., Asif, M., Soliman, M.H. and Ali, S., 2019. Lead toxicity induced phytotoxic effects on mung bean can be relegated by lead tolerant *Bacillus subtilis* (PbRB3). *Chemosphere*, *234*, pp.70-80. doi: 10.1016/j.chemosphere.2019.06.024

Armendariz, A. L., Talano, M. A., Oller, A. L. W., Medina, M. I., & Agostini, E. (2015). Effect of arsenic on tolerance mechanisms of two plant growth-promoting bacteria used as biological inoculants. *Journal of Environmental Sciences*, *33*, 203-210. doi: 10.1016/j.jes.2014.12.024

Arroyo-Herrera, I., Rojas-Rojas, F. U., Lozano-Cervantes, K. D., Larios-Serrato, V., Vásquez-Murrieta, M. S., Whtiman, W. B., ... & Estrada-de Los Santos, P. (2020). Draft genome of five *Cupriavidus plantarum* strains: agave, maize and sorghum plant-associated bacteria with resistance to metals. *3 Biotech*, *10*, 1-10. doi: [10.1007/s13205-020-02210-8](https://doi.org/10.1007/s13205-020-02210-8)

Asaf, S., Khan, A. L., Khan, M. A., Al-Harrasi, A., & Lee, I. J. (2018). Complete genome sequencing and analysis of endophytic *Sphingomonas* sp. LK11 and its potential in plant growth. *3 Biotech*, *8*(9), 1-14. doi: [10.1007/s13205-018-1403-z](https://doi.org/10.1007/s13205-018-1403-z)

Banerjee, S., Datta, S., Chattyopadhyay, D., & Sarkar, P. (2011). Arsenic accumulating and transforming bacteria isolated from contaminated soil for potential use in bioremediation. *Journal of Environmental Science and Health, Part A*, *46*(14), 1736-1747. doi: [10.1080/10934529.2011.623995](https://doi.org/10.1080/10934529.2011.623995)

Belimov, A. A., Hontzeas, N., Safronova, V. I., Demchinskaya, S. V., Piluzza, G., Bullitta, S., & Glick, B. R. (2005). Cadmium-tolerant plant growth-promoting bacteria associated with the roots of Indian mustard (*Brassica juncea* L. Czern.). *Soil Biology and Biochemistry*, *37*(2), 241-250. doi: [10.1016/j.soilbio.2004.07.033](https://doi.org/10.1016/j.soilbio.2004.07.033)

Belimov, A. A., Kunakova, A. M., Safronova, V. I., Stepanok, V. V., Yudkin, L. Y., Alekseev, Y. V., & Kozhemyakov, A. P. (2004). Employment of rhizobacteria for the inoculation of barley plants cultivated in soil contaminated with lead and cadmium. *Microbiology*, *73*(1), 99-106. doi: [10.1023/B:MICI.0000016377.62060.d3](https://doi.org/10.1023/B%3AMICI.0000016377.62060.d3)

Bensidhoum, L., Nabti, E., Tabli, N., Kupferschmied, P., Weiss, A., Rothballer, M., ... & Hartmann, A. (2016). Heavy metal tolerant *Pseudomonas protegens* isolates from agricultural well water in northeastern Algeria with plant growth promoting, insecticidal and antifungal activities. *European Journal of Soil Biology*, *75*, 38-46. doi: 10.1016/j.ejsobi.2016.04.006

Bilal, S., Shahzad, R., Khan, A. L., Kang, S. M., Imran, Q. M., Al-Harrasi, A., ... & Lee, I. J. (2018). Endophytic microbial consortia of phytohormones-producing fungus *Paecilomyces formosus* LHL10 and bacteria *Sphingomonas* sp. LK11 to Glycine max L. regulates physio-hormonal changes to attenuate aluminum and zinc stresses. *Frontiers in plant science*, *9*, 1273. doi: [10.3389/fpls.2018.01273](https://doi.org/10.3389/fpls.2018.01273)

Bruno, L. B., Karthik, C., Ma, Y., Kadirvelu, K., Freitas, H., & Rajkumar, M. (2020). Amelioration of chromium and heat stresses in *Sorghum bicolor* by Cr6+ reducing-thermotolerant plant growth promoting bacteria. *Chemosphere*, *244*, 125521. doi: [10.1016/j.chemosphere.2019.125521](https://doi.org/10.1016/j.chemosphere.2019.125521)

Cavalca, L., Zanchi, R., Corsini, A., Colombo, M., Romagnoli, C., Canzi, E., & Andreoni, V. (2010). Arsenic-resistant bacteria associated with roots of the wild *Cirsium arvense* (L.) plant from an arsenic polluted soil, and screening of potential plant growth-promoting characteristics. *Systematic and applied microbiology*, *33*(3), 154-164. doi: 10.1016/j.syapm.2010.02.004

Chen, W. M., Wu, C. H., James, E. K., & Chang, J. S. (2008). Metal biosorption capability of *Cupriavidus taiwanensis* and its effects on heavy metal removal by nodulated *Mimosa pudica*. *Journal of Hazardous Materials*, *151*(2-3), 364-371. doi: [10.1016/j.jhazmat.2007.05.082](https://doi.org/10.1016/j.jhazmat.2007.05.082)

Chiboub, M., Saadani, O., Fatnassi, I. C., Abdelkrim, S., Abid, G., Jebara, M., & Jebara, S. H. (2016). Characterization of efficient plant-growth-promoting bacteria isolated from *Sulla coronaria* resistant to cadmium and to other heavy metals. *Comptes rendus biologies*, *339*(9-10), 391-398. doi: 10.1016/j.crvi.2016.04.015

Dary, M., Chamber-Pérez, M. A., Palomares, A. J., & Pajuelo, E. (2010). “In situ” phytostabilisation of heavy metal polluted soils using *Lupinus luteus* inoculated with metal resistant plant-growth promoting rhizobacteria. *Journal of Hazardous Materials*, *177*(1-3), 323-330. doi: 10.1016/j.jhazmat.2009.12.035

Das, J., & Sarkar, P. (2018). Remediation of arsenic in mung bean (*Vigna radiata*) with growth enhancement by unique arsenic-resistant bacterium *Acinetobacter lwoffii*. *Science of the total environment*, *624*, 1106-1118. doi: [10.1016/j.scitotenv.2017.12.157](https://doi.org/10.1016/j.scitotenv.2017.12.157)

Das, S., Jean, J. S., Kar, S., Chou, M. L., & Chen, C. Y. (2014). Screening of plant growth-promoting traits in arsenic-resistant bacteria isolated from agricultural soil and their potential implication for arsenic bioremediation. *Journal of hazardous materials*, *272*, 112-120. doi: 10.1016/j.jhazmat.2014.03.012

Dimkpa, C., Svatoš, A., Merten, D., Büchel, G., & Kothe, E. (2008). Hydroxamate siderophores produced by *Streptomyces acidiscabies* E13 bind nickel and promote growth in cowpea (*Vigna unguiculata* L.) under nickel stress. *Canadian Journal of Microbiology*, *54*(3), 163-172. doi: [10.1139/W07-130](https://doi.org/10.1139/W07-130)

Faisal, M., & Hasnain, S. (2006). Growth stimulatory effect of *Ochrobactrum intermedium* and *Bacillus cereus* on *Vigna radiata* plants. *Letters in applied microbiology*, *43*(4), 461-466. doi: 10.1111/j.1472-765X.2006.01977.x

Felestrino, É.B., Vieira, I.T., Caneschi, W.L., Cordeiro, I.F., Assis, R.D.A.B., de Carvalho Lemes, C.G., Fonseca, N.P., Sanchez, A.B., Cepeda, J.C.C., Ferro, J.A. and Garcia, C.C.M., 2018. Biotechnological potential of plant growth-promoting bacteria from the roots and rhizospheres of endemic plants in ironstone vegetation in southeastern Brazil. *World Journal of Microbiology and Biotechnology*, *34*(10), pp.1-14.

Gusain, P., Paliwal, R. and Singh, V., 2017. Rhizoremediation of cadmium-contaminated soil associated with hydroxamate siderophores isolated from Cd-resistant plant growth–promoting *Dietzia maris* and *Lysinibacillus* strains. *International journal of phytoremediation*, *19*(3), pp.290-299.

Han, H., Sheng, X., Hu, J., He, L., & Wang, Q. (2018b). Metal-immobilizing *Serratia liquefaciens* CL-1 and *Bacillus thuringiensis* X30 increase biomass and reduce heavy metal accumulation of radish under field conditions. *Ecotoxicology and environmental safety*, *161*, 526-533. doi: 10.1016/j.ecoenv.2018.06.033

Han, H., Wang, Q., He, L. Y., & Sheng, X. F. (2018a). Increased biomass and reduced rapeseed Cd accumulation of oilseed rape in the presence of Cd-immobilizing and polyamine-producing bacteria. *Journal of hazardous materials*, *353*, 280-289. doi: 10.1016/j.jhazmat.2018.04.024

Han, J. I., Choi, H. K., Lee, S. W., Orwin, P. M., Kim, J., LaRoe, S. L., ... & Han, C. (2011). Complete genome sequence of the metabolically versatile plant growth-promoting endophyte *Variovorax paradoxus* S110. *Journal of bacteriology*, *193*(5), 1183-1190. doi: 10.1128/JB.00925-10

Hao, X., Xie, P., Johnstone, L., Miller, S. J., Rensing, C., & Wei, G. (2012). Genome sequence and mutational analysis of plant-growth-promoting bacterium *Agrobacterium tumefaciens* CCNWGS0286 isolated from a zinc-lead mine tailing. *Applied and Environmental Microbiology*, *78*(15), 5384-5394. doi: 10.1128/AEM.01200-12

Hao, X., Xie, P., Zhu, Y. G., Taghavi, S., Wei, G., & Rensing, C. (2015). Copper tolerance mechanisms of *Mesorhizobium amorphae* and its role in aiding phytostabilization by *Robinia pseudoacacia* in copper contaminated soil. *Environmental science & technology*, *49*(4), 2328-2340. doi: 10.1021/es504956a

He, L. Y., Zhang, Y. F., Ma, H. Y., Chen, Z. J., Wang, Q. Y., Qian, M., & Sheng, X. F. (2010). Characterization of copper-resistant bacteria and assessment of bacterial communities in rhizosphere soils of copper-tolerant plants. *Applied Soil Ecology*, *44*(1), 49-55. doi: 10.1016/j.apsoil.2009.09.004

Hemambika, B., & Kannan, V. R. (2012). Intrinsic characteristics of Cr 6+-resistant bacteria isolated from an electroplating industry polluted soils for plant growth-promoting activities. *Applied biochemistry and biotechnology*, *167*(6), 1653-1667. doi: 10.1007/s12010-012-9606-y

Hemambika, B., Balasubramanian, V., Rajesh Kannan, V., & Arthur James, R. (2013). Screening of chromium-resistant bacteria for plant growth-promoting activities. *Soil and Sediment Contamination: An International Journal*, *22*(7), 717-736. doi: 10.1080/15320383.2013.768199

Huang, J., Liu, Z., Li, S., Xu, B., Gong, Y., Yang, Y., & Sun, H. (2016). Isolation and engineering of plant growth promoting rhizobacteria *Pseudomonas aeruginosa* for enhanced cadmium bioremediation. *The Journal of general and applied microbiology*. doi: 10.2323/jgam.2016.04.007

Kamaruzzaman, M.A., Abdullah, S.R.S., Hasan, H.A., Hassan, M. and Idris, M., 2019. Potential of hexavalent chromium-resistant rhizosphere bacteria in promoting plant growth and hexavalent chromium reduction. *Journal of Environmental Biology*, *40*(3), pp.427-433. doi: 10.22438/jeb/40/3(SI)/Sp-03

Kang, S. M., Asaf, S., Khan, A. L., Khan, A., Mun, B. G., Khan, M. A., ... & Lee, I. J. (2020). Complete genome sequence of *Pseudomonas psychrotolerans* CS51, a plant growth-promoting bacterium, under heavy metal stress conditions. *Microorganisms*, *8*(3), 382. doi: 10.3390/microorganisms8030382

Kang, S. M., Asaf, S., Kim, S. J., Yun, B. W., & Lee, I. J. (2016). Complete genome sequence of plant growth-promoting bacterium *Leifsonia xyli* SE134, a possible gibberellin and auxin producer. *Journal of biotechnology*, *239*, 34-38. doi: [10.1016/j.jbiotec.2016.10.004](https://doi.org/10.1016/j.jbiotec.2016.10.004)

Karthik, C., Oves, M., Sathya, K., Sri Ramkumar, V., & Arulselvi, P. I. (2017). Isolation and characterization of multi-potential *Rhizobium* strain ND2 and its plant growth-promoting activities under Cr (VI) stress. *Archives of Agronomy and Soil Science*, *63*(8), 1058-1069. doi: 10.1080/03650340.2016.1261116

Khan, A. L., Ullah, I., Hussain, J., Kang, S. M., Al‐Harrasi, A., Al‐Rawahi, A., & Lee, I. J. (2016). Regulations of essential amino acids and proteomics of bacterial endophytes *Sphingomonas* sp. L k11 during cadmium uptake. *Environmental toxicology*, *31*(7), 887-896. doi: [10.1002/tox.22100](https://doi.org/10.1002/tox.22100)

Khan, A. L., Waqas, M., Kang, S. M., Al-Harrasi, A., Hussain, J., Al-Rawahi, A., ... & 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. doi: [10.1007/s12275-014-4002-7](https://doi.org/10.1007/s12275-014-4002-7)

Kour, R., Jain, D., Bhojiya, A. A., Sukhwal, A., Sanadhya, S., Saheewala, H., ... & Mohanty, S. R. (2019). Zinc biosorption, biochemical and molecular characterization of plant growth-promoting zinc-tolerant bacteria. *3 Biotech*, *9*(11), 1-17. doi: [10.1007/s13205-019-1959-2](https://doi.org/10.1007/s13205-019-1959-2)

Kushwaha, A., Rani, R., Kumar, S., Thomas, T., David, A. A., & Ahmed, M. (2017). A new insight to adsorption and accumulation of high lead concentration by exopolymer and whole cells of lead-resistant bacterium *Acinetobacter junii* L. Pb1 isolated from coal mine dump. *Environmental Science and Pollution Research*, *24*(11), 10652-10661. doi: 10.1007/s11356-017-8752-8

Li, Y., Pang, H. D., He, L. Y., Wang, Q., & Sheng, X. F. (2017). Cd immobilization and reduced tissue Cd accumulation of rice (*Oryza sativa* wuyun-23) in the presence of heavy metal-resistant bacteria. *Ecotoxicology and environmental safety*, *138*, 56-63. doi: 10.1016/j.ecoenv.2016.12.024

Lin, X., Mou, R., Cao, Z., Xu, P., Wu, X., Zhu, Z., & Chen, M. (2016). Characterization of cadmium-resistant bacteria and their potential for reducing accumulation of cadmium in rice grains. *Science of the Total Environment*, *569*, 97-104. doi: 10.1016/j.scitotenv.2016.06.121

Liu, C., Lin, H., Dong, Y., Li, B., & Wang, L. (2019). Identification and characterization of plant growth–promoting endophyte RE02 from *Trifolium repens* L. in mining smelter. *Environmental Science and Pollution Research*, *26*(17), 17236-17247. doi: [10.1007/s11356-019-04904-w](https://doi.org/10.1007/s11356-019-04904-w)

Luziatelli, F., Ficca, A. G., Cardarelli, M., Melini, F., Cavalieri, A., & Ruzzi, M. (2020). Genome sequencing of *Pantoea agglomerans* C1 provides insights into molecular and genetic mechanisms of plant growth-promotion and tolerance to heavy metals. *Microorganisms*, *8*(2), 153. doi: [10.3390/microorganisms8020153](https://doi.org/10.3390/microorganisms8020153)

Ma, H., Wei, M., Wang, Z., Hou, S., Li, X., & Xu, H. (2020). Bioremediation of cadmium polluted soil using a novel cadmium immobilizing plant growth promotion strain *Bacillus* sp. TZ5 loaded on biochar. *Journal of hazardous materials*, *388*, 122065. doi: [10.1016/j.jhazmat.2020.122065](https://doi.org/10.1016/j.jhazmat.2020.122065)

Madhaiyan, M., Poonguzhali, S., & Sa, T. (2007). Metal tolerating methylotrophic bacteria reduces nickel and cadmium toxicity and promotes plant growth of tomato (*Lycopersicon esculentum* L.). *Chemosphere*, *69*(2), 220-228. doi: 10.1016/j.chemosphere.2007.04.017

Mallick, I., Bhattacharyya, C., Mukherji, S., Dey, D., Sarkar, S. C., Mukhopadhyay, U. K., & Ghosh, A. (2018). Effective rhizoinoculation and biofilm formation by arsenic immobilizing halophilic plant growth promoting bacteria (PGPB) isolated from mangrove rhizosphere: a step towards arsenic rhizoremediation. *Science of The Total Environment*, *610*, 1239-1250. doi: 10.1016/j.scitotenv.2017.07.234

Mello, I.S., Pietro-Souza, W., Barros, B.M., da Silva, G.F., Campos, M.L. and Soares, M.A., 2019. Endophytic bacteria mitigate mercury toxicity to host plants. *Symbiosis*, *79*(3), pp.251-262.

Mitra, S., Pramanik, K., Ghosh, P. K., Soren, T., Sarkar, A., Dey, R. S., ... & Maiti, T. K. (2018). Characterization of Cd-resistant *Klebsiella michiganensis* MCC3089 and its potential for rice seedling growth promotion under Cd stress. *Microbiological research*, *210*, 12-25. doi: 10.1016/j.micres.2018.03.003

Naik, M.M. and Dubey, S.K., 2011. Lead-enhanced siderophore production and alteration in cell morphology in a Pb-resistant *Pseudomonas aeruginosa* strain 4EA. *Current microbiology*, *62*(2), pp.409-414.

Nonnoi, F., Chinnaswamy, A., de la Torre, V. S. G., de la Peña, T. C., Lucas, M. M., & Pueyo, J. J. (2012). Metal tolerance of rhizobial strains isolated from nodules of herbaceous legumes (*Medicago* spp. and *Trifolium* spp.) growing in mercury-contaminated soils. *Applied soil ecology*, *61*, 49-59. doi: [10.1016/j.apsoil.2012.06.004](https://doi.org/10.1016/j.apsoil.2012.06.004)

Nookongbut, P., Kantachote, D., Krishnan, K., & Megharaj, M. (2017). Arsenic resistance genes of As‐resistant purple nonsulfur bacteria isolated from As‐contaminated sites for bioremediation application. *Journal of basic microbiology*, *57*(4), 316-324. doi: [10.1002/jobm.201600584](https://doi.org/10.1002/jobm.201600584)

Nookongbut, P., Kantachote, D., Megharaj, M., & Naidu, R. (2018). Reduction in arsenic toxicity and uptake in rice (*Oryza sativa* L.) by As-resistant purple nonsulfur bacteria. *Environmental Science and Pollution Research*, *25*(36), 36530-36544. doi: [10.1007/s11356-018-3568-8](https://doi.org/10.1007/s11356-018-3568-8)

Pal, A. K., & Sengupta, C. (2019). Isolation of cadmium and lead tolerant plant growth promoting rhizobacteria: *Lysinibacillus varians* and *Pseudomonas putida* from Indian Agricultural Soil. *Soil and Sediment Contamination: An International Journal*, *28*(7), 601-629. doi: [10.1080/15320383.2019.1637398](https://doi.org/10.1080/15320383.2019.1637398)

Pandey, N., & Bhatt, R. (2016). Role of soil associated *Exiguobacterium* in reducing arsenic toxicity and promoting plant growth in Vigna radiata. *European Journal of Soil Biology*, *75*, 142-150. doi: [10.1016/j.ejsobi.2016.05.007](https://doi.org/10.1016/j.ejsobi.2016.05.007)

Park, J. H., Bolan, N., Megharaj, M., & Naidu, R. (2011a). Isolation of phosphate solubilizing bacteria and their potential for lead immobilization in soil. *Journal of hazardous materials*, *185*(2-3), 829-836. doi: 10.1016/j.jhazmat.2010.09.095

Park, J. H., Bolan, N., Megharaj, M., & Naidu, R. (2011b). Concomitant rock phosphate dissolution and lead immobilization by phosphate solubilizing bacteria (*Enterobacter* sp.). *Journal of environmental management*, *92*(4), 1115-1120. doi: 10.1016/j.jenvman.2010.11.031

Pereira, S. I. A., & Castro, P. M. L. (2014). Diversity and characterization of culturable bacterial endophytes from *Zea mays* and their potential as plant growth-promoting agents in metal-degraded soils. *Environmental Science and Pollution Research*, *21*(24), 14110-14123. doi: 10.1007/s11356-014-3309-6

Pinter, I.F., Salomon, M.V., Berli, F., Bottini, R. and Piccoli, P., 2017. Characterization of the As (III) tolerance conferred by plant growth promoting rhizobacteria to in vitro-grown grapevine. *Applied Soil Ecology*, *109*, pp.60-68.

Quiñones, M. A., Ruiz-Díez, B., Fajardo, S., López-Berdonces, M. A., Higueras, P. L., & Fernández-Pascual, M. (2013). *Lupinus albus* plants acquire mercury tolerance when inoculated with an Hg-resistant *Bradyrhizobium* strain. *Plant physiology and biochemistry*, *73*, 168-175. doi: 10.1016/j.plaphy.2013.09.015

Rajkumar, M., Ma, Y., & Freitas, H. (2013). Improvement of Ni phytostabilization by inoculation of Ni resistant *Bacillus megaterium* SR28C. *Journal of environmental management*, *128*, 973-980. doi: 10.1016/j.jenvman.2013.07.001

Rajkumar, M., Nagendran, R., Lee, K.J. and Lee, W.H., 2005. Characterization of a Novel Cr 6+ Reducing *Pseudomonas* sp. with Plant Growth–Promoting Potential. *Current Microbiology*, *50*(5), pp.266-271.

Rizvi, A., & Khan, M. S. (2018). Heavy metal induced oxidative damage and root morphology alterations of maize (*Zea mays* L.) plants and stress mitigation by metal tolerant nitrogen fixing *Azotobacter chroococcum*. *Ecotoxicology and environmental safety*, *157*, 9-20. doi: [10.1016/j.ecoenv.2018.03.063](https://doi.org/10.1016/j.ecoenv.2018.03.063)

Rodríguez‐Llorente, I. D., Gamane, D., Lafuente, A., Dary, M., El Hamdaoui, A., Delgadillo, J., ... & Pajuelo, E. (2010). Cadmium biosorption properties of the metal‐resistant *Ochrobactrum cytisi* Azn6. 2. *Engineering in Life Sciences*, *10*(1), 49-56. doi: 10.1002/elsc.200900060

Ruiz-Díez, B., Quiñones, M. A., Fajardo, S., López, M. A., Higueras, P., & Fernández-Pascual, M. (2012). Mercury-resistant rhizobial bacteria isolated from nodules of leguminous plants growing in high Hg-contaminated soils. *Applied microbiology and biotechnology*, *96*(2), 543-554. doi: 10.1007/s00253-011-3832-z

Sagar, S., Dwivedi, A., Yadav, S., Tripathi, M., & Kaistha, S. D. (2012). Hexavalent chromium reduction and plant growth promotion by *Staphylococcus arlettae* strain Cr11. *Chemosphere*, *86*(8), 847-852. doi: 10.1016/j.chemosphere.2011.11.031

Seneviratne, M., Gunaratne, S., Bandara, T., Weerasundara, L., Rajakaruna, N., Seneviratne, G., & Vithanage, M. (2016). Plant growth promotion by *Bradyrhizobium japonicum* under heavy metal stress. *South African Journal of Botany*, *105*, 19-24. doi: 10.1016/j.sajb.2016.02.206

Shafique, M., Jawaid, A., & Rehman, Y. (2017). As (V) reduction, As (III) oxidation, and Cr (VI) reduction by multi-metal-resistant *Bacillus subtilis, Bacillus safensis*, and *Bacillus cereus* species isolated from wastewater treatment plant. *Geomicrobiology Journal*, *34*(8), 687-694. doi: [10.1080/01490451.2016.1240265](https://doi.org/10.1080/01490451.2016.1240265)

Shagol, C. C., Krishnamoorthy, R., Kim, K., Sundaram, S., & Sa, T. (2014). Arsenic-tolerant plant-growth-promoting bacteria isolated from arsenic-polluted soils in South Korea. *Environmental Science and Pollution Research*, *21*(15), 9356-9365. doi: 10.1007/s11356-014-2852-5

Shi, X., Zhou, G., Liao, S., Shan, S., Wang, G., & Guo, Z. (2018). Immobilization of cadmium by immobilized *Alishewanella* sp. WH16-1 with alginate-lotus seed pods in pot experiments of Cd-contaminated paddy soil. *Journal of hazardous materials*, *357*, 431-439. doi: 10.1016/j.jhazmat.2018.06.027

Singh, N., Gupta, S., Marwa, N., Pandey, V., Verma, P. C., Rathaur, S., & Singh, N. (2016b). Arsenic mediated modifications in *Bacillus aryabhattai* and their biotechnological applications for arsenic bioremediation. *Chemosphere*, *164*, 524-534. doi: 10.1016/j.chemosphere.2016.08.119

Singh, N., Marwa, N., Mishra, J., Verma, P. C., Rathaur, S., & Singh, N. (2016a). *Brevundimonas diminuta* mediated alleviation of arsenic toxicity and plant growth promotion in *Oryza sativa* L. *Ecotoxicology and environmental safety*, *125*, 25-34. doi: 10.1016/j.ecoenv.2015.11.020

Tariq, S., Amin, A. and Latif, Z., 2015. PCR based DNA fingerprinting of mercury resistant and nitrogen fixing *Pseudomonas* spp. *Pure and Applied Biology*, *4*(1), p.129.

Touceda-González, M., Brader, G., Antonielli, L., Ravindran, V. B., Waldner, G., Friesl-Hanl, W., ... & Sessitsch, A. (2015). Combined amendment of immobilizers and the plant growth-promoting strain *Burkholderia phytofirmans* PsJN favours plant growth and reduces heavy metal uptake. *Soil Biology and Biochemistry*, *91*, 140-150. doi: [10.1016/j.soilbio.2015.08.038](https://doi.org/10.1016/j.soilbio.2015.08.038)

Trivedi, P., Pandey, A., & Sa, T. (2007). Chromate reducing and plant growth promoting activies of psychrotrophic *Rhodococcus erythropolis* MtCC 7905. *Journal of basic microbiology*, *47*(6), 513-517. doi: 10.1002/jobm.200700224

Wang, X., Nie, Z., He, L., Wang, Q., & Sheng, X. (2017). Isolation of As-tolerant bacteria and their potentials of reducing As and Cd accumulation of edible tissues of vegetables in metal (loid)-contaminated soils. *Science of the Total Environment*, *579*, 179-189. doi: 10.1016/j.scitotenv.2016.10.239

Wani, P. A., & Khan, M. S. (2010). Bacillus species enhance growth parameters of chickpea (*Cicer arietinum* L.) in chromium stressed soils. *Food and Chemical Toxicology*, *48*(11), 3262-3267. doi: 10.1016/j.fct.2010.08.035

Wani, P. A., & Khan, M. S. (2013). Nickel detoxification and plant growth promotion by multi metal resistant plant growth promoting *Rhizobium* species RL9. *Bulletin of environmental contamination and toxicology*, *91*(1), 117-124. doi: 10.1007/s00128-013-1002-y

Wani, P. A., Zainab, I. O., Wasiu, I. A., & Jamiu, K. O. (2015). Chromium (VI) reduction by *Streptococcus* species isolated from the industrial area of Abeokuta, Ogun State, Nigeria. *Research Journal of Microbiology*, *10*(2), 66. doi: 10.3923/jm.2015.66.75

Wani, P.A., Khan, M.S. and Zaidi, A., 2007. Chromium reduction, plant growth–promoting potentials, and metal solubilizatrion by *Bacillus* sp. isolated from alluvial soil. *Current microbiology*, *54*(3), pp.237-243.

Wu, S. C., Peng, X. L., Cheung, K. C., Liu, S. L., & Wong, M. H. (2009). Adsorption kinetics of Pb and Cd by two plant growth promoting rhizobacteria. *Bioresource technology*, *100*(20), 4559-4563.

Wu, S.C., Cheung, K.C., Luo, Y.M. and Wong, M.H., 2006. Effects of inoculation of plant growth-promoting rhizobacteria on metal uptake by *Brassica juncea*. *Environmental Pollution*, *140*(1), pp.124-135. doi: [10.1016/j.biortech.2009.04.037](https://doi.org/10.1016/j.biortech.2009.04.037)

Xia, X., Li, J., Liao, S., Zhou, G., Wang, H., Li, L., ... & Wang, G. (2016). Draft genomic sequence of a chromate-and sulfate-reducing *Alishewanella* strain with the ability to bioremediate Cr and Cd contamination. *Standards in genomic sciences*, *11*(1), 1-8. doi: 10.1186/s40793-016-0169-3

Xu, X., Xu, M., Zhao, Q., Xia, Y., Chen, C., & Shen, Z. (2018). Complete genome sequence of Cd (II)-resistant *Arthrobacter* sp. PGP41, a plant growth-promoting bacterium with potential in microbe-assisted phytoremediation. *Current microbiology*, *75*(9), 1231-1239. doi: 1[0.1007/s00284-018-1515-z](https://doi.org/10.1007/s00284-018-1515-z)

Yang, E., Sun, L., Ding, X., Sun, D., Liu, J. and Wang, W., 2019. Complete genome sequence of *Caulobacter flavus* RHGG3 T, a type species of the genus *Caulobacter* with plant growth-promoting traits and heavy metal resistance. *3 Biotech*, *9*(2), p.42. doi: [10.1007/s13205-019-1569-z](https://doi.org/10.1007/s13205-019-1569-z)

Yuan, Z., Yi, H., Wang, T., Zhang, Y., Zhu, X., & Yao, J. (2017). Application of phosphate solubilizing bacteria in immobilization of Pb and Cd in soil. *Environmental Science and Pollution Research*, *24*(27), 21877-21884. doi: 10.1007/s11356-017-9832-5

Zhang, X. X., & Rainey, P. B. (2007). The role of a P1-type ATPase from *Pseudomonas fluorescens* SBW25 in copper homeostasis and plant colonization. *Molecular plant-microbe interactions*, *20*(5), 581-588. doi: 10.1094/MPMI -20-5-0581.

Zhou, G., Xia, X., Wang, H., Li, L., Wang, G., Zheng, S., & Liao, S. (2016). Immobilization of lead by *Alishewanella* sp. WH16-1 in pot experiments of Pb-contaminated paddy soil. *Water, Air, & Soil Pollution*, *227*(9), 1-11. doi: 10.1007/s11270-016-3040-7

Zribi, K., Djébali, N., Mrabet, M., Khayat, N., Smaoui, A., Mlayah, A., & Aouani, M. E. (2012). Physiological responses to cadmium, copper, lead, and zinc of *Sinorhizobium* sp. strains nodulating *Medicago sativa* grown in Tunisian mining soils. *Annals of microbiology*, *62*(3), 1181-1188. doi: 10.1007/s13213-011-0358-7