SCIENTIFIC NOTE

Assessment of physicochemical characteristics of biofertilizers and their role in the rooting capacity of plants

Evaluación de las características fisicoquímicas de biofertilizantes y su papel sobre la capacidad de enraizamiento de plantas

Astghik Karapetyan[1*]

ABSTRACT

The concentration of supplied mineral nutrients is one of the most important and limiting factors for enhancing the efficiency of plant nutrition. Optimal concentration of nutrient solutions (NS) provide plants with the necessary amount of nutrients. From this point of view, research on several physicochemical parameters that characterize concentrations of NS and uptake of nutrients by the plants remains an actual problem. The changes of electrical conductivity (EC) and total dissolved solids (TDS) depending on the concentration of biofertilizer as well as the role of biofertilizer solutions in the rooting capacity of cuttings (lateral sprouts) of *Callisia fragrans* are presented here. The EC and TDS of the biofertilizer-water mixture changed gradually according to the biofertilizer concentration. The biofertilizer solution was a good medium for the rooting of *C. fragrans* cuttings. The results could help to provide the crops with the necessary amount of mineral nutrients and regulate the suitability of irrigation during the entire vegetation period.

Key words: electrical conductivity, total dissolved solids, nutrient solution, sustainable agriculture, hydroponics, *Callisia fragrans*.

RESUMEN

La concentración de los nutrientes minerales suministrados es uno de los factores más importantes y limitantes para mejorar la eficiencia nutritiva de las plantas. La concentración óptima de la disolución nutritiva (DN) proporciona a las plantas la cantidad necesaria de nutrientes. Desde este punto de vista, la investigación sobre varios parámetros fisicoquímicos que caracterizan la concentración de la DN y la absorción de nutrientes por parte de las plantas sigue siendo un problema en la actualidad. Se muestran aquí los cambios de conductividad eléctrica (CE) y de los sólidos disueltos totales (SDT) en función de la concentración del biofertilizante, así como el papel de la disolución del biofertilizante sobre la capacidad de enraizamiento de las estacas (brotes laterales) de *Callisia fragrans*. Ambos parámetros CE y SDT de la mezcla biofertilizante con agua, cambian gradualmente dependiendo de la concentración del biofertilizante. La solución del biofertilizante fue un buen medio para el enraizamiento de estacas de *C. fragrans*. Los resultados podrían ayudar a proporcionar a los cultivos la cantidad necesaria de nutrientes y regular la idoneidad del riego durante todo el periodo vegetativo.

Palabras clave: conductividad eléctrica, sólidos disueltos totales, solución nutritiva, agricultura sustentable, hidroponía, *Callisia fragrans*.

Introduction

Biofertilizers are formulations composed of living latent cells of efficient strains of various microorganisms that help plants take up nutrients during the interaction in the rhizosphere. Due to the number of advantages these eco-friendly products are very popular in modern agriculture. Application of biofertilizers reduces and/or totally excludes the amount not only of chemical fertilizers, but also pesticides, insecticides, fungicides, and other chemicals and decrease the dangerous impact of chemicals on the environment. Due to special compositions, biofertilizers improve soil fertility and enhance crop productivity by providing healthy and ecologically safe bioproducts. Application of biofertilizers is an effective approach to sustainable agriculture. Biofertilizers are actively used for rooting cuttings, seed germination, and foliar nutrition (Wong *et al*., 2015; Alori & Babalola, 2018; González-Díaz *et al*., 2019). Nowadays, there are various biofertilizers in the global market labeled under different trademarks. The microorganisms of biofertilizers mostly include the N-fixing, P-solubilizing, P-mobilizing, K-solubilizing, S-oxidizing, Zn-solubilizing species, and plant growth promoting Rhizobacteria (PGPR) (Antoun & Prevost, 2005; Fuentes-Ramirez & Caballero, 2005; Vessey, 2015; Anli *et al*., 2020; Fasusi *et al*., 2021).

Received for publication: January 11, 2022. Accepted for publication: June 3, 2022. Doi: 10.15446/agron.colomb.v40n2.100425

1 Laboratory of Plant Nutrition and Productivity, G.S. Davtyan Institute of Hydroponics Problems, National Academy of Sciences of the Republic of Armenia, Yerevan (Armenia).

* Corresponding author: astghik84k@rambler.ru

Agriculture in regions with a dry climate may benefit from biofertilizers (Schütz *et al.*, 2018). González-Díaz *et al.* (2019) observe that biofertilizers inoculated with nitrogen fixing bacteria of the genera *Azotobacter* and *Azospirillum* contribute to the crop yield of *Eucalyptus grandis*. In another study (Onyia *et al.*, 2020), growth and yield of maize significantly improve when treated with biofertilizer. Moreover, the applied biofertilizer protect the plants from pathogen/insect attack (Onyia *et al.*, 2020).

Biofertilizers improve soil chemical and physical characteristics including with long-term action (Demir, 2020; Wang *et al.*, 2021). Biofertilizers are effective for application in both open and protected crops (Wu *et al.*, 2005; El-Ghandour *et al.*, 2009; González-Díaz *et al.*, 2019; Demir, 2020; Bergstrand, 2022).

The concentration of supplied nutrients is one of the most important and limiting factors for enhancing the efficiency of plant nutrition. If the concentration of nutrients is extremely low, plant growth is lowered. Extremely high concentrations of nutrients lead to osmotic stress, ionic toxicity, and growth restrictions (Sakamoto & Suzuki, 2020). Optimal concentrations of nutrient solutions (NS) will provide the plants with the necessary amount of nutrients. Two main parameters that best characterize the concentration of NS are electrical conductivity (EC) and total dissolved solids (TDS). Optimization of the concentration of NS is becoming an urgent issue, especially in hydroponics, as the nutrients in the supplied solution remain the main source for the plant nutrition. The EC of NS in hydroponics is in the range 0.8–4.0 dS m^{-1} (Sambo *et al.*, 2019).

The requirement for a concentration of NS, and therefore of an optimal EC and TDS of the NS, may be different for each plant. For example, Ding *et al.* (2018) showed that, for the hydroponic production of pakchoi, the optimal EC treatment should be 1.8 or 2.4 dS m^{-1}.

In conventional hydroponic systems, inorganic fertilizers are very common, as organic compounds in the NS inhibit plant growth and have been regarded as phytotoxic (Shinohara *et al.*, 2011). On the other hand, the use of organic fertilizers in hydroponics is important, as it will allow recycling organic compounds. Therefore, the application of biofertilizers in hydroponics remains the focus of the active study (Lee & Lee, 2015; Mendes *et al.*, 2017; Dewi *et al.*, 2021).

Research on several physicochemical parameters characterizing concentrations of NS and uptake of nutrients by the plants remains an actual problem.

In the frame of this study, changes were considered for the two most important parameters: EC and TDS in organic solutions of biofertilizer, depending on the concentration, as well as the role of the solution of the biofertilizer on the rooting capacity of the valuable medicinal plant *Callisia fragrans*.

Materials and methods

The experiments were carried out at the Laboratory of Plant Nutrition and Productivity of the G.S. Davtyan Institute of Hydroponic Problems (National Academy of Sciences, Republic of Armenia).

In the study, a biofertilizer Ecobiofeed+® was used. It was developed by the "Armbiotechnology" Scientific and Production Center (National Academy of Sciences, Republic of Armenia). This ecologically safe bioproduct, based on natural raw material, contains zeolites and a complex of nitrogen-fixing microorganisms: *Azotobacter vinelandii* (strain AV1) (Avetisova *et al.*, 2021) and *Rhizobium pusense* (strain RP1). This biofertilizer provides plants with macro- and microelements, vitamins, and protein amino acids.

Preparation of nutrient solution

The nutrient solution (NS) was prepared according to the following steps:

A) Ten ml of the biofertilizer were added to the glass container that contains 1000 ml of water (solution A). After the measurements, 10 ml of the biofertilizer were added to the solution A. This process was repeated by adding 10 ml of the biofertilizer each time, until content of the biofertilizer in solution A became 100 ml (solution B). The following ratios (v/v) of the biofertilizer and water were in this prepared solution: 0.01:1, 0.02:1, 0.03:1, 0.04:1, 0.05:1, 0.06:1, 0.07:1, 0.08:1, 0.09:1, and 0.1:1.

B) One hundred ml of the biofertilizer were added to the solution B. After the measurements, 100 ml of the biofertilizer were added to the solution B. This process repeated by adding for 100 ml of the biofertilizer each time, until the volume of the biofertilizer in solution B became 1000 ml. The following ratios (v/v) of the biofertilizer and water were in the obtained solution: 0.1:1, 0.2:1; 0.3:1, 0.4:1, 0.5:1, 0.6:1, 0.7:1, 0.8:1, 0.9:1, and 1.0:1.

Electrical conductivity and total dissolved solids

Electrical conductivity (EC) and total dissolved solids (TDS) of biofertilizer solution were measured depending on the concentration. Measurements were done with the nutrient meter (Bluelab Truncheon Nutrient Meter, New Zealand). Resolution of the equipment was 50 mg L^{-1}, 0.1 mS cm^{-1}, and equipment accuracy: ± 50 mg L^{-1}, ± 0.1 mS cm^{-1}.

Rooting capacity

The lateral sprouts (cuttings without leaf rosette) of valuable medicinal plant *Callisia fragrans* were used. The plants were grown under open-air hydroponic conditions of the Ararat Valley (Karapetyan, 2020). Standard (10–15 cm length) cuttings of lateral sprouts were taken from the plants and immediately placed in plastic cups with a volume of 150 ml (5 cuttings per cup). The cups were filled up with a 120 ml solution of the biofertilizer-water and placed in a laboratory-controlled condition (18–20°C). Rooting was checked up daily. Along with the reduction of the volume of the solution, fresh solution of the biofertilizer-water was added, keeping the total volume at 120 ml. The solution of biofertilizer-water was prepared according to the following ratio: 10 ml of the biofertilizer was added to the 1000 ml of water.

Data analysis

Data were presented as means ± standard deviation SD (n= 4) that were calculated using GraphPad Prism 8 Software Package. The graphs were created with Microsoft Excel 2016.

Results and discussion

Electrical conductivity

In nutrient solutions (NS) containing 100 ml of the biofertilizer, electrical conductivity (EC) reached up to 1.05 mS cm^{-1}. Moreover, each 20 ml of the biofertilizer increased the value by 0.1 mS cm^{-1} (Fig. 1A). Upon increasing the concentration, the EC changed accordingly: the addition of each 100 ml of biofertilizer increased EC from 0.1:1 to 0.2:1 ratio by 0.5 mS cm^{-1}, from 0.2:1 to 0.5:1 ratio by 0.3 mS cm^{-1}, from 0.5:1 to 0.7:1 by 0.2 mS cm^{-1}, 0.7:1 to 1.0:1 by 0.15 mS cm^{-1} (Fig. 1B). EC of water was 0.5 mS cm^{-1}.

Total dissolved solids

In NS containing 100 ml of the biofertilizer, TDS reached up to 525 mg L^{-1}. Moreover, each 20 ml of the biofertilizer increased the value by 50 mg L^{-1} (Fig. 2A). Upon increasing the concentration, TDS changed according in the following: each 100 ml of biofertilizer added TDS: from 0.1:1 to 0.2:1 by 250 mg L^{-1}, 0.2:1 to 0.5:1 by 150 mg L^{-1}, 0.5:1 to 0.7:1 by 100 mg L^{-1}, 0.7:1 to 1.0:1 by 75 mg L^{-1} (Fig. 2B). TDS of water was 250 mg L^{-1}.

The changes of the above values were faster in comparatively diluted solutions. Upon increases of the concentration the changes became less. This could be explained by the fact that saturated solutions were created, and further addition of the fertilizer did not play a significant role on the strength level of the solution.

Rooting capacity

After 2-3 d from the beginning of the experiments the cuttings of *C. fragrans* that were placed in the solution of the biofertilizer-water developed green sprouts. Moreover, within two weeks all cuttings developed roots. In other studies, the efficiency of biofertilizers on the rooting of the plants has also been confirmed. Gortari *et al.* (2019) prove that mini-cuttings of yerba mate inoculated with *Trichoderma asperelloides* is distinguished by high rooting capacity as well as a great number and length of the roots. Efficiency of plant growth promoting microorganisms (PGPM) on rooting in plant tissue culture is also approved (Soumare *et al.*, 2021). The rooting percentage of *Eucalyptus* cuttings

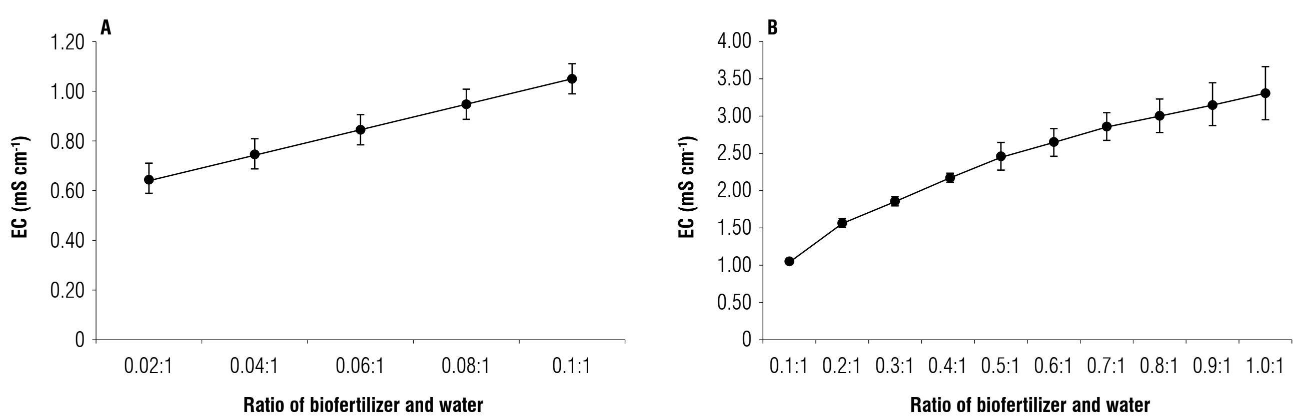

FIGURE 1. Electrical conductivity (EC) of biofertilizer solution depending on the ratio (v/v) of biofertilizer and water: A) from 0.01:1 to 0.1:1, B) from 0.1:1 to 1.0:1. Data are the mean of four replicates ± standard deviation.

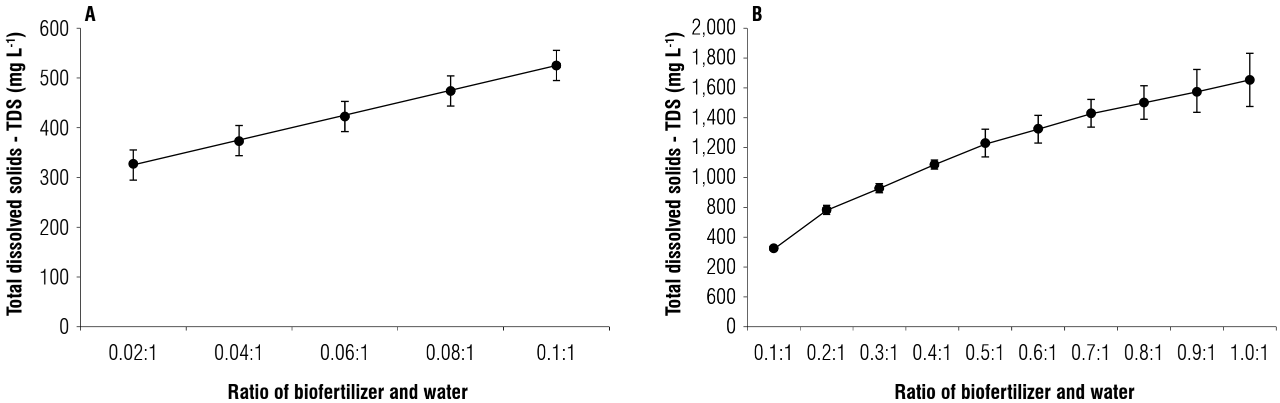

FIGURE 2. Total dissolved solids (TDS) of biofertilizer solution depending on the ratio (v/v) of biofertilizer and water: A) from 0.01:1 to 0.1:1, B) from 0.1:1 to 1.0:1. Data are the mean of four replicates ± standard deviation.

increases during interaction between indole-3-butyric acid and biofertilizer (Rajabi *et al.*, 2015).

Conclusion

The EC and TDS of the biofertilizer-water solution changed gradually depending on the biofertilizer concentration. Moreover, the changes were faster in comparatively diluted solutions, upon increasing the concentration the changes became less. Within two weeks all cuttings developed roots. The measurement of EC and TDS of the applied NS could be important for evaluating the suitability of irrigation. The findings of the present paper are important for the application of biofertilizers in agriculture and provide valuable information.

Conflict of interest statement

The author declares that there is no conflict of interests regarding the publication of this article.

Author's contributions

AK developed and conducted the experiments, carried out the statistical analysis, interpreted the study data and wrote the scientific note.

Literature cited

Alori, E. T., & Babalola, O. O. (2018). Microbial inoculants for improving crop quality and human health in Africa. *Frontiers in Microbiology*, *9*, Article 2213. https://doi.org/10.3389/fmicb.2018.02213

Anli, M., Baslam, M., Tahiri, A., Raklami, A., Simanczik, S., Boutasknit, A., Ait-El-Mokhtar, M., Ben-Laouane, R., Toubali, S., Rahou, Y. A., Chitt, M. A., Oufdou, K., Mitsui, T., Hafidi, M., & Meddich, A. (2020). Biofertilizers as strategies to improve photosynthetic apparatus, growth, and drought stress tolerance in the date Palm. *Frontiers in Plant Science*, *11*, Article 516818. https://doi.org/10.3389/fpls.2020.516818

Antoun, H., & Prévost, D. (2005). Ecology of plant growth promoting rhizobacteria. In Z. A. Siddiqui (Ed.), *PGPR*: *Biocontrol and biofertilization* (pp. 1–38). Springer. https://doi.org/10.1007/1-4020-4152-7_1

Avetisova, G., Melkonyan, L., Toplaghaltsyan, A., Tsarukyan, G., Keleshyan, S., Karapetyan, Z., & Ghochikyan, V. (2021, October 20). *Co-cultivation of L-tryptophan-producing strain Brevibacterium flavum and Azotobacter vinelandii as an alternative method for indole-3-acetic acid production* [Conference presentation]. International Scientific and Practical Conference «Biotechnology: Science and Practice. Innovation and Business», Yerevan, Armenia.

Bergstrand, K. J. (2022). Organic fertilizers in greenhouse production systems – a review. *Scientia Horticulturae*, *295*, Article 110855. https://doi.org/10.1016/j.scienta.2021.110855

Demir, Z. (2020). Effects of microbial bio-fertilizers on soil physicochemical properties under different soil water regimes in greenhouse grown eggplant (*Solanum melongena* L.). *Communications in Soil Science and Plant Analysis*, *51*(14), 1888–1903. https://doi.org/10.1080/00103624.2020.1798983

Dewi, A. K., Rahayu, S., Dwimahyani, I., Khairunnisa, N., & Suryadi, E. (2021). The combination of irradiation biofertilizer of rhizosphere microbes consortium inoculant (IMR) and inorganic fertilizer on the growth of kale in a floating raft hydroponic system. *IOP Conference Series: Earth and Environmental Science*, *924*, Article 012007. https://doi.org/10.1088/1755-1315/924/1/012007

Ding, X., Jiang, Y., Zhao, H., Guo, D., He, L., Liu, F., Zhou, Q., Nandwani, D., Hui, D., & Yu, J. (2018). Electrical conductivity of nutrient solution influenced photosynthesis, quality, and antioxidant enzyme activity of pakchoi (*Brassica campestris* L. ssp. *Chinensis*) in a hydroponic system. *PLoS ONE*, *13*(8), Article e0202090. https://doi.org/10.1371/journal.pone.0202090

El-Ghandour, I. A., Desouky, E. M., Galal, Y. G. M., Arafa, R. A., & Abou Seer, A. M. M. (2009). Effect of biofertilizers and organic phosphorus amendments on growth and essential oil of marjoram (*Majorana hortensis* L.). *Egyptian Academic Journal of Biological Sciences, G. Microbiology, 1*(1), 29–36. https://doi.org/10.21608/EAJBSG.2009.16715

Fasusi, O. A., Cruz, C., & Babalola, O. O. (2021). Agricultural sustainability: microbial biofertilizers in rhizosphere management, *Agriculture*, *11*(2), Article 163. https://doi.org/10.3390/agriculture11020163

Fuentes-Ramírez, L. E., & Caballero-Mellado, J. (2005). Bacterial biofertilizers. In Z. A. Siddiqui (Ed.), *PGPR: Biocontrol and biofertilization* (pp. 143–172). Springer. https://doi.org/10.1007/1-4020-4152-7_5

González-Díaz, A., Ojeda-Morales, M. E., Hernández-Rivera, M. A., Córdova-Bautista, Y., Díaz-Flores, L. L., López-Lázaro J. S., & Álvarez-Ramírez J. G. (2019). Effect of biofertilizers application on the growth of *Eucalyptus grandis* seedlings under greenhouse conditions. *Journal of Plant Nutrition*, *42*(19), 2560–2576. https://doi.org/10.1080/01904167.2019.1655040

Gortari, F., Nowosad, M. I. P., Laczeski, M. E., Onetto, A., Cortese, I. J., Castrillo, M. L., Bich, G. A., Alvarenga, A. E., Lopez, A. C., Villalba, L., Zapata, P. D., Rocha, P., & Niella, F. (2019). Biofertilizers and biocontrollers as an alternative to the use of chemical fertilizers and fungicides in the propagation of yerba mate by mini-cuttings. *Revista Árvore*, *43*(4), Article e430412. https://doi.org/10.1590/1806-90882019000400012

Karapetyan, A. S. (2020). Biosynthesis of anthocyanins in the medicinal raw material of *Callisia fragrans* under open-air hydroponic conditions of Ararat Valley. *Biological Journal of Armenia, 72* (1–2), 159–161 (in Armenian).

Lee, S., & Lee, J. (2015). Beneficial bacteria and fungi in hydroponic systems: Types and characteristics of hydroponic food production methods. *Scientia Horticulturae*, *195*(*12*), 206–215. https://doi.org/10.1016/j.scienta.2015.09.011

Mendes, L. A., Barione, P. P., Atoloye, I. A., Landgraf, M. D., & Rezende, M. O. O. (2017). From agricultural residues to biofertilizers: preparation and characterization for use in hydroponics. *American Open Chemistry Journal*, *3*(1), 1–14.

Onyia, C. O., Okoh, A. M., & Okoh, I. (2020). Production of plant growth-promoting bacteria biofertilizer from organic waste material and evaluation of its performance on the growth of corn (*Zea mays*). *American Journal of Plant Sciences*, *11*(2), 189–200.http://doi.org/10.4236/ajps.2020.112015

Rajabi, M., Chaichi, M., & Azizi, A. (2015). Interaction of IBA and bio-fertilizer on rooting of eucalyptus cuttings. *Plant Products Technology*, *14(2)*, 181–192.

Sakamoto, M., & Suzuki, T. (2020). Effect of nutrient solution concentration on the growth of hydroponic sweetpotato. *Agronomy*, *10*(11), Article 1708. https://doi.org/10.3390/agronomy10111708

Sambo, P., Nicoletto, C., Giro, A., Pii, Y., Valentinuzzi, F., Mimmo T., Lugli P., Orzes, G., Mazzetto, F., Astolfi, S., Terzano, R., & Cesco, S. (2019). Hydroponic solutions for soilless production systems: issues and opportunities in a smart agriculture perspective. *Frontiers in Plant Science, 10*, Article 923. https://doi.org/10.3389/fpls.2019.00923

Schütz, L., Gattinger, A., Meier, M., Müller, A., Boller, T., Mäder, P., & Mathimaran, N. (2018). Improving crop yield and nutrient use efficiency via biofertilization—A global meta-analysis. *Frontiers in Plant Science*, *8*, Article 2204. https://doi.org/10.3389/fpls.2017.02204

Shinohara, M., Aoyama, C., Fujiwara, K., Watanabe, A., Ohmori, H., Uehara, Y., & Takano, M. (2011). Microbial mineralization of organic nitrogen into nitrate to allow the use of organic fertilizer in hydroponics. *Soil Science and Plant Nutrition, 57*(2), 190–203. https://doi.org/10.1080/00380768.2011.554223

Soumare, A., Diédhiou, A. G., Arora, N. K., Al-Ani, L. K. T., Ngom, M., Fall, S., Hafidi, M., Ouhdouch, Y., Kouisni, L., & Sy, M. O. (2021). Potential role and utilization of plant growth promoting microbes in plant tissue culture. *Frontiers in Microbiol*ogy, *12*, Article 649878. https://doi.org/10.3389/fmicb.2021.649878

Vessey, J. K. (2003). Plant growth promoting rhizobacteria as biofertilizers. *Plant and Soil*, *255,* 571–586. https://doi.org/10.1023/A:1026037216893

Wang, Y., Peng, S., Hua, Q., Qiu, C., Wu, P., Liu, X., & Lin, X. (2021). The long-term effects of using phosphate-solubilizing bacteria and photosynthetic bacteria as biofertilizers on peanut yield and soil bacteria community. *Frontiers in Microbiology, 12*, Article 693535. https://doi.org/10.3389/fmicb.2021.693535

Wong, W. S., Tan, S. N., Ge, L., Chen, X., & Yong, & J. W. H. (2015). The importance of phytohormones and microbes in biofertilizers. In D. Maheshwari (Ed.), *Bacterial metabolites in sustainable agroecosystem* (pp. 105–158). Springer. https://doi.org/10.1007/978-3-319-24654-3_6

Wu, S. C., Cao, Z. H., Li, Z. G., Cheung, K. C., & Wong, M. H. (2005). Effects of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: a greenhouse trial. *Geoderma*, *121*(1-2), 155–166. https://doi.org/10.1016/j.geoderma.2004.07.003