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Editorial: Molecular and biochemical effects exerted by the interaction of symbiotic microorganisms with plants to improve their response to environmental stresses

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Editorial on the Research Topic
Molecular and biochemical effects exerted by the interaction of symbiotic microorganisms with plants to improve their response to environmental stresses

Climate change negatively influences several activities dedicated to human food security, and agriculture in particular is one of the most affected. Extended periods of high temperatures, drought, and higher salinity, among other environmental stresses, cause problems in the normal growth of vegetal organisms (Grossiord et al., 2020). In this context, the scientific challenge is to find cost-effective solutions to generate crops that are tolerant to multiple stress factors (Zandalinas et al., 2021).

However, plants display a suite of mechanisms to mitigate the negative impact of stress in general (Taìtrai et al., 2016). Plants can live in association with fungal, bacterial, and other soil microorganisms in a functional symbiosis that can boost those mechanisms (Barrera et al., 2020; Hereme et al., 2020; Pérez-Alonso et al., 2020; Morales-Quintana et al., 2022).

Much of the research exploring the effects of root fungal endophytes on plant nutrition focuses on phosphorus (Pi), with little attention paid to other important nutrients. In this Research Topic, Conchillo et al. explored the role of the root-colonizing fungus *Serendipita indica* on potassium (K) nutrition in *Arabidopsis thaliana* plants. They combined manipulative experiments with molecular approaches in an attempt to understand not only the role of the fungus on plant growth and K^+ uptake but also the underlying mechanisms. In isolation, the growth of *S. indica* was inhibited by high levels of K^+. In symbiosis, the presence of *S. indica* did not improve the biomass accumulation of plants nor the uptake of the element under K^+ starvation. This came as a surprise, since the presence of *S. indica* stimulated the expression of the gene AtHAK5, which encodes for a high-affinity K^+ transporter in *Arabidopsis* (Qi et al., 2008). While the symbiosis benefits were mainly controlled by the level of Pi (it improved plant growth under low levels of Pi), a higher mycelial colonization of plant roots was observed under low levels of K^+. Since this nutritional restrictive condition was shown to favor root fungal colonization with no apparent benefit conferred on the host plant, low levels of K^+ seem to trigger a parasitic behavior of the fungal endophyte. Context dependency in symbiotic interactions between plants and microorganisms can be determined by the environmental level of resources (e.g., radiation, nitrogen) and incidence of abiotic factors (e.g., temperature, UVb) (Bastías et al., 2022; Bastias and Gundel, 2023). In this regard, Conchillo et al. showed that this can even be more complex, since it can be determined by varying levels of essential macronutrients (here, K^+ and Pi) and the different requirements/demands of the symbiotic partners for growth.

Regarding saline stress, high salinity in soils provokes physiological and biochemical disorders in plants, thus triggering a decrease in crop yield and even death (Park et al., 2016). Wild species can grow under extreme climatic conditions, including drought, heat, and high soil saline concentration, as in the case of *Chenopodium quinoa* in the Atacama Desert (Fuentes and Bhargava, 2011; Bascuñán-Godoy et al., 2016). González-Teuber et al. evaluated the synergic protective activity of two root fungal endophytes on quinoa exposed to a high saline concentration. The authors previously identified and isolated those two fungal endophytes from quinoa plants, and they were classified as *Talaromyces minioluteus* and *Penicillium murcianum* (González-Teuber et al., 2017). Here, the authors showed that quinoa plants inoculated with both endophytes display better morphological traits and physiological and biochemical performance under saline conditions. Endophyte inoculation increases the chemical and enzymatic protective mechanisms of plants. The antioxidant activity of SOD, APX, and POD enzymes was improved by over 50%, in addition to an increase in the phenolic content of about 30%. The fungal endophytes could be interacting in a synergistic association, improving the saline stress response more than single-species inoculation.

However, plant–microbe interactions are not necessarily static but show a highly dynamic character, which implies constant communication between the symbionts to maintain the mutual interest in the interaction. In their work, Rouina et al. explored the molecular basis of communication between *Trichoderma* spp. and *Arabidopsis thaliana*. Interestingly, a previous study highlighted the change in lifestyle of the fungus with increasing salinity in the media (Tseng et al., 2020). The fungus was described as promoting plant growth under moderate salt stress conditions (50 mM NaCl), while no plant growth-promoting effect was observed under higher salt conditions (>100 mM NaCl). Under the latter conditions, the host plants retained a higher tolerance to salt stress and biotic foes, as evidenced by the significantly lower contents of enzymes with antioxidant activities in plants infected with the fungi. However, at the same time, the fungus changed to a more saprophytic lifestyle, posing additional stress for the host plant. Here, Rouina et al. presented a comprehensive proteomics study to investigate dynamic changes in the secretome and, thus, in the communication between both partners, providing evidence for the secretion of symbiosis- and salt concentration-specific proteins from both the host plant and the fungal endophyte. For example, the authors suggested that Arabidopsis ß-glucosidase PYK10 and a fungal prenylcysteine lyase are involved in the promotion of plant growth under moderate salt stress. However, the data also revealed that both partners must invest more in the maintenance of the symbiosis when the stress conditions increase, which implies that the mutualistic partners constantly gauge the stress conditions and adapt according to the prevailing environmental conditions.

The article collection in this Research Topic provides important information about the effects and mechanisms underlying the symbiosis between endophytes and their host plants in response to environmental stresses. This information constitutes valuable advances in the knowledge required to understand the relationship between fungal endophytes and plants so that new eco-friendly strategies to cope with the adverse effects of climate change, which can improve the performance of crops to guarantee food security, may be designed.

Author contributions

PR, PG, and SP wrote and reviewed the editorial and the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Barrera, A., Hereme, R., Ruiz-Lara, S., Larrondo, L. F., Gundel, P. E., Pollmann, S., et al. (2020). Fungal endophytes enhance the photoprotective mechanisms and photochemical efficiency in the Antarctic *Colobanthus quitensis* (Kunth) Bartl. Exposed to UV-B radiation. *Front. Ecol. Evol.* 8, 122. doi: 10.3389/fevo.2020.00122

Bascuñán-Godoy, L., Reguera, M., Blumwald, Y. M., and Blumwald, E. (2016). Water deficit stress-induced changes in carbon and nitrogen partitioning in *Chenopodium quinoa* Willd. *Planta* 243, 591–603. doi: 10.1007/s00425-015-2424-z

Bastías, D. A., Balestrini, R., Pollmann, S., and Gundel, P. E. (2022). Environmental interference of plant microbe interactions. *Plant Cell Environ.* 45, 3387–3398. doi: 10.1111/pce.14455

Bastias, D. A., and Gundel, P. E. (2023). Plant stress responses compromise mutualisms with Epichloë endophytes. *J. Exp. Bot.* 74, 19–23. doi: 10.1093/jxb/erac428

Fuentes, F., and Bhargava, A. (2011). Morphological analysis of quinoa germplasm grown under lowland desert conditions. *J. Agron. Crop Sci.* 197, 124–134. doi: 10.1111/j.1439-037X.2010.00445.x

González-Teuber, M., Vilo, C., and Bascuñán-Godoy, L. (2017). Molecular characterization of endophytic fungi associated with the roots of *Chenopodium quinoa* inhabiting the Atacama Desert, Chile. *Genom. Data* 11, 109–112. doi: 10.1016/j.gdata.2016.12.015

Grossiord, C., Buckley, T. N., Cernusak, L. A., Novick, K. A., Poulter, B., Siegwolf, R. T. W., et al. (2020). Plant responses to rising vapor pressure deficit. *New Phytol.* 226, 1550–1566. doi: 10.1111/nph.16485

Hereme, R., Morales-Navarro, S., Ballesteros, G., Barrera, A., Ramos, P., Gundel, P. E., et al. (2020). Fungal endophytes exert positive effects on *Colobanthus quitensis* under water stress but neutral under a projected climate change scenario in Antarctica. *Front. Microbiol.* 11, 264. doi: 10.3389/fmicb.2020.00264

Morales-Quintana, L., Moya, M., Santelices-Moya, R., Cabrera-Ariza, A., Rabert, C., Pollmann, S., et al. (2022). Improvement in the physiological and biochemical performance of strawberries under drought stress through symbiosis with Antarctic fungal endophytes. *Front. Microbiol.* 13, 939955. doi: 10.3389/fmicb.2022.939955

Park, H. J., Kim, W. Y., and Yun, D. J. (2016). A new insight of salt stress signaling in plant. *Mol. Cells.* 39, 447–459. doi: 10.14348/molcells.2016.0083

Pérez-Alonso, M. M., Guerrero-Galán, C., Scholz, S. S., Kiba, T., Sakakibara, H., Ludwig-Müller, J., et al. (2020). Harnessing symbiotic plant-fungus interactions to unleash hidden forces from extreme plant ecosystems. *J. Exp. Bot.* 71, 3865–3877. doi: 10.1093/jxb/eraa040

Qi, Z., Hampton, C. R., Shin, R., Barkla, B. J., White, P. J., Schachtman, D. P., et al. (2008). The high affinity K+ transporter AtHAK5 plays a physiological role in planta at very low K+ concentrations and provides a caesium uptake pathway in Arabidopsis. *J. Exp. Bot.* 59, 595–607. doi: 10.1093/jxb/erm330

Taìtrai, Z. A., Zsuzsanna, R. S., Mancarella, S., Orsini, F., and Gianquinto, G. (2016). Morphological and physiological plant responses to drought stress in *Thymus citriodorus*. *Intern. J. Agron.* 2016, 4165750. doi: 10.1155/2016/4165750

Tseng, Y. H., Rouina, H., Groten, K., Rajani, P., Furch, A. C. U., Reichelt, M., et al. (2020). An endophytic trichoderma strain promotes growth of its hosts and defends against pathogen attack. *Front. Plant Sci.* 11, 573670. doi: 10.3389/fpls.2020.573670

Zandalinas, S. I., Fritschi, F. B., and Mittler, R. (2021). Global warming, climate change, and environmental pollution: recipe for a multifactorial stress combination disaster. *Trends Plant Sci.* 26, 588–599. doi: 10.1016/j.tplants.2021.02.011