Ecofarming (e-Magazine)

Agriculture

Ecofarming
e-Magazine for Agriculture and Allied Sciences
http://www.ecofarming.rdagriculture.in
e-ISSN: 2583-0791

# Improving Stress Management

## by Endophytes and Physiological Processes in Rice Under Water Stress Condition

1. **Laxmipriya Behera,** ICAR-National Rice Research Institute, Cuttack, Odisha, India
2. **Ujalarashmi Shau,** ICAR-National Rice Research Institute, Cuttack, Odisha, India and Faculty of Agricultural Science, SOA University, Bhubaneswar, India
3. **Rupak Jena,** ICAR-National Rice Research Institute, Cuttack, Odisha, India
4. **Awadhesh Kumar,** ICAR-National Rice Research Institute, Cuttack, Odisha, India
5. **Ravinder Kumar,** ICAR-Indian Agricultural Research Institute, New Delhi
6. **Rahul Kumar Tiwari,** ICAR-Indian Institute of Sugarcane Research, Lucknow, India
7. **M.J. Baig,** ICAR-National Rice Research Institute, Cuttack, Odisha, India
8. **Amaresh Kumar Nayak,** ICAR-National Rice Research Institute, Cuttack, Odisha, India
9. **Milan Kumar Lal,** ICAR-National Rice Research Institute, Cuttack, Odisha, India

Email: milan.lal@icar.gov.in; milan2925@gmail.com

***Received: February, 2024; Accepted: February, 2024; Published: April, 2024***

**Abstract**

To develop remedies to mitigate the adverse impacts of frequent extreme weather events on agricultural productivity, exacerbated by climate change, it is crucial to understand the role of endophytes. In order to support plant growth, endophytes play a multifaceted role by enhancing nutrient uptake and protecting plants from a variety of biotic and abiotic stresses at the same time. Furthermore, they contribute to the production of hormones within plants, which are crucial to the regulation of growth and development. Additionally, endophytes produce a wide range of secondary metabolites with pharmaceutical, agricultural, and industrial potential, including antimicrobials, antioxidants, and enzymes, all of which have pharmaceutical and agricultural applications. Endophytes offer promising solutions for improving crop resilience and ensuring food security in the face of changes in climatic conditions due to their ability to strengthen plant immune systems as well as boost nutrient uptake. Endophytes hold a great deal of promise when it comes to the potential for sustainable agriculture practices and the discovery of new natural products.

## Effect of climate change on rice plant

Food production is constantly impacted by climate change. One of the most significant manifestations of this phenomenon is the steady rise in average global temperatures. As a result of this warming trend, extreme weather events like severe droughts are exacerbated. These droughts, characterized by prolonged periods of minimal precipitation, are crucial in controlling the evaporation of soil moisture and the accumulation of salts in the soil. Nevertheless, droughts are becoming increasingly common worldwide and often coincide with heat waves, compounding the challenges to agricultural systems. Extreme heat and prolonged drought pose a significant threat to agricultural productivity. In addition, heat stress can directly affect crop health and yield, further reducing agricultural output (Alam et al. 2011). High temperatures accelerate evaporation rates, causing soil moisture to be rapidly depleted. Additionally, drought can have long-term consequences for land productivity due to soil degradation caused by moisture depletion and salt accumulation. Food security challenges in affected regions are exacerbated by salt accumulation, which renders soil unsuitable for cultivation (Parry et al., 1999).

Adaptation and mitigation strategies are essential to addressing the complex interplay between climate change, drought, and food production. The soil moisture can be conserved during dry periods by utilizing sustainable water management practices, such as rainwater harvesting and efficient irrigation techniques. Climate-induced stress on food systems can be mitigated by investing in drought-resistant crop varieties and resilient agricultural practices (Wassmann, R.et al., 2009)). As a result, a growing frequency of severe droughts and heat waves caused by climate change poses significant challenges to global food production. In order to safeguard agricultural resilience against climate change, it is crucial to recognize the multifaceted nature of this issue (Parry *et al.*, 1999). It is an essential food for about two-thirds of the world's population. We need between thirty and eighty percent of our daily calories in Asia. Rice (*Oryza sativa* L.), the primary grain crop, provides more than half of the world's population with their fundamental food (Ganie et al. 2014). Global rice consumption is projected to reach 520.8 million tons in 2021–2022, up 1.5% from the previous season (FAO 2021). In the coming years, the demand for rice will likely increase even more due to the alarming population growth rate. However, the growing demand for rice coincides with the anticipated escalation of climate change's effects on rice production (Bartels, Dorothea; Sunkar, Ramanjulu, 2005). As a result of climate change, rice crops will be more susceptible to both biotic and abiotic stresses, which could result in significant reductions in grain quality and productivity. According to research, important crops are stressed by biotic and abiotic stressors like salt, drought, and high temperatures. Those are the biggest barriers to agricultural productivity (Negrao et al., 2011).

## Microbes are friends or Foe

Abiotic stress factor tolerance was not the primary focus of most genetic advancements made during the green revolution, which is why many contemporary cereal crops, for example, rice are sensitive to harsh environmental circumstances they need more water for better production. This case deals with the breeders' pursuit of characteristics that boost resistance to abiotic stress. In addition to heat stress, drought, salinity, and nutrient deficiencies, climate change is expected to worsen abiotic stresses (Stuart J Roy; Elise J Tucker; Mark Tester, 2011). In rice-growing regions, higher temperatures and irregular rainfall patterns can exacerbate water scarcity, resulting in more frequent and prolonged droughts. Furthermore, increased salinity levels in soil and water bodies, coupled with nutrient imbalances, can affect rice growth and development, resulting in lower grain yields and quality (Chitnis 2020 in VR). They also aid in the recycling of nutrients and act as biotransformers for a variety of substances followed by (Fig. 1). Endophytes are widely distributed and largely unexplored, but as our understanding of plant-microbe interactions expands, more endophytes with a wider range of functions

are described in (Table 1 and Table 2) being found. (M Kamran and others, 2022).

## Microbes are friends or Foe

Abiotic stress factor tolerance was not the primary focus of most genetic advancements made during the green revolution, which is why many contemporary cereal crops, for example, rice are sensitive to harsh environmental circumstances they need more water for better production. This case deals with the breeders' pursuit of characteristics that boost resistance to abiotic stress.

In addition to heat stress, drought, salinity, and nutrient deficiencies, climate change is expected to worsen abiotic stresses (Stuart J Roy; Elise J Tucker; Mark Tester, 2011). In rice-growing regions, higher temperatures and irregular rainfall patterns can exacerbate water scarcity, resulting in more frequent and prolonged droughts. Furthermore, increased salinity levels in soil and water bodies, coupled with nutrient imbalances, can affect rice growth and development, resulting in lower grain yields and quality (Chitnis 2020 in VR).

They also aid in the recycling of nutrients and act as bio transformers for a variety of substances followed by (Fig. 1). Endophytes are widely distributed and largely unexplored, but as our understanding of plant-microbe interactions expands, more endophytes with a wider range of functions are described in (Table 1 and Table 2) being found. (M Kamran and others, 2022).

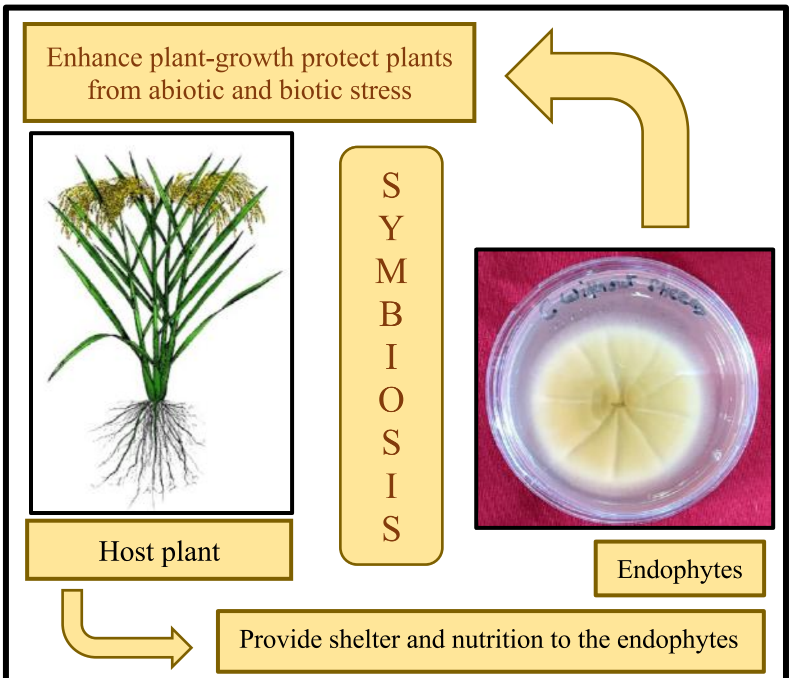


Fig. 1 Symbiotic relationship between plants and microbes

**Table 1:** List of Endophytes mediating abiotic stress tolerance in plants.

| Endophyte | Host Plant | Stress | Mechanism | Reference |
|---|---|---|---|---|
| *Trichoderma harzianum TH-56* | *Oryza sativa* | Drought | Upregulation of aquaporin, dehydrin, and malondialdehyde genes | Pandey *et al.*, 2016 |
| *Mucilaginibacter stain K* | *Arabidopsis thaliana* | Salinity | Increase in anti-oxidative defense machinery | Fan D and Smith DL (2022) |
| *Azospirillum lipoferum* | *Sugarcane (Saccharum officinarum)* | Alleviated drought stress | Produced ABA, IAA, Giberlic acid maintained RWC | (Cohen *et al.* 2009; Reinhardt *et al.* 2008) |
| *Pantoea agglomerans* | *Zea mays* | Salinity | Aquaporins upregulation | |

| | | | | |
|---|---|---|---|---|
| *Arthrobacter endophyticus, Nocardiopsis alba* | *A. thaliana* | Salinity | The expression of a gene involved in Glycerolipid, nitrogen phenylalanine metabolism water, potassium ion absorption | |
| *Pseudomonas putida* | *Cicer arietinum* | Drought | The role of targeted miRNAs and their gene in stress regulation of drought stress | Jatan, Ram; Chauhan, Puneet Singh; Lata, Charu (2018) |
| *Pseudomonas azotophicus* | *Sugarcane (Saccharum officinarum)* | Drought stress | Activation of drouht stress-responsive gene and ethylene signaling pathways | (Vargas *et al.*, 2024) |
| *Alternaria chlamydospora* | *Triticum aestivum* | salinity | Inducing the physiological and biochemical responses | Shrivastava, P. and Kumar, R, (2015) |
| *Bacillus amyloliquifaciens* | *Grapevine* | Drought stress | Secreted melatonin reduced MDA, $H_2O_2$,$O_2^-$ | (Jiao *et al.* 2016) |
| *Pantoea alhagi* | *Wheat (Triticum aestivum)* | Drought and salt stress | Increased soluble sugar, IAA, EPS, and Sidderephore production decrease proline, MDA, and also chlorophyll degradation | (Chen *et al.*2017) |

**Table 2:** List of Endophytes associated with biotic stress.

| Endophyte | Host Plant | Plant-Pathogen | Target Pathway | Reference |
|---|---|---|---|---|
| *Bacillus spp* | *Oryza sativa* | *Pyricularia oryzae* | Induce systemic resistance | Morelli M, Bahar O, et al., (2020) |
| *Daldinia eschscholtzii* | *Zingiber officinale, stemona tuberosa* | *Colletotrichum acutatum, Sclerotium rolfsii* | Production of antifungal compounds | Suebrasri, Thanapat, et al., (2020) |
| *Paraconiothyrium sp.* | *Fraxinus excelsior* | *Hymenoscyphus fraxineus* | unknown | Ganley, R. J., Sniezko, R. A., & Newcombe, G. (2008) |
| *Cladosporium spp.* | *Pinus monticola* | *Cronartium Ribicola* | Induced resistance | Morelli M, Bahar O, et al., (2020) |
| *Bacillus spp* | *Oryza sativa* | *Pyricularia oryzae* | Antioxidant defense activities | Morelli M, Bahar O, et al., (2020) |
| *Phomopis cassie* | *Cassia spectabilis* | *Cladosporium sphaerospermum* | unknown | Silva, Geraldo H et.al., (2005) |
| *Streptomyces strain, DEF09* | *Triticum aestivum* | *Fusarium graminearum* | Chitinase production | Colombo, Elena Maria, et al., (2019) |

| | | | | |
|---|---|---|---|---|
| *Rhizobium etli* | *Phaseolus vulgaris* | *Pseudomonas syringae* | Callose deposition, SA, and JA-dependent gene induction | Morelli, Massimiliano, et al., (2020) |
| *Bacillus spp.* | *N nicotiana tabacum* | *Pseudomonas syringae tobacco* | Induce systemic resistance | Morelli, Massimiliano, et al., (2020) |
| *Paenibacillus* | *Triticum aestivum* | *Mycosphaerella graminicola* | Defense pathway | Samain, E., Aussenac, T., & Selim, S. (2019) |

## How Endophytes will help plant

### a. Nutrients uptake

Plant tissues are home to a variety of beneficial microorganisms called endophytes, which help plants absorb essential nutrients. By absorbing macronutrients and micronutrients from the soil and organic matter around them, these microorganisms contribute significantly to the health and productivity of plants (Rana et al. 2020). Moreover, endophytes play a crucial role in facilitating the uptake of micronutrients, including zinc, iron, and copper, which are essential for various physiological processes in plants. These microorganisms can produce chelating compounds that bind to micronutrients in the soil, preventing their precipitation and increasing their availability for plant uptake (García-Latorre, C., Rodrigo, S., Santamaría, O. 2021). Furthermore, endophytes can stimulate the expression of plant genes involved in micronutrient uptake and transport, further enhancing the plant's ability to acquire these essential elements. Plant growth, development, and resilience to environmental stress are enhanced when endophytes are present within plant tissues (Aleynova, Olga A et al., 2023). Sustainable agriculture practices aimed at optimizing nutrient utilization and promoting crop productivity in diverse agroecosystems can benefit from harnessing the beneficial interactions between endophytes and their host plants (Indira and Gajjela, et al. 2021).

## Production of phytohormones

Endophytes can generate cytokinins, auxins, and gibberellins (GAs). Even though these molecules are just as crucial for plant growth in various environmental situations as chemical signaling and messengers, the potential for endophytic fungi to produce phytohormones, particularly gibberellins, is understudied (Khan et al. 2015). And fungi mostly generate indole-3-acetic acid (IAA) as an auxin. The primary controllers of plant growth, auxins have several advantageous effects on shoot and root development, including the induction of the root formation process, elongation and division of cells, responses to tropism, and differentiation of vascular tissue (Jaroszuk-Ściseł et al. 2014).

### b. Production of secondary metabolites

Endophytes are a rich source of chemicals that benefit their hosts in addition to boosting the plant to produce defense compounds (Card et al. 2016; Lugtenberg et al. 2016; Latz et al. 2018; Kaddes et al. 2019). As a source of bioactive chemicals, endophytes are not only beneficial to the host plant but also contribute to the production of defense compounds (Fadiji AE and Babalola OO, (2020). A wide variety of secondary metabolites are produced by these microbial inhabitants, which have potential for pharmaceutical, agricultural, and industrial purposes. Bioactive compounds include antimicrobials, antioxidants, anticancer compounds, and enzymes. Plant pathogens can be inhibited by endophyte-derived chemicals, thereby protecting the host plant from disease (Singh, V. K., & Kumar, A. (2023). Furthermore, endophytes stimulate the production of defense compounds in their host plants through their symbiotic interactions. Plants synthesize phytoalexins, pathogenesis-related proteins, and other defense compounds as a result of these symbiotic interactions. By strengthening the plant's immune system, these compounds enable it to withstand stress from pests, pathogens, and environmental fluctuations, both biotic and abiotic. They are excellent producers of compounds that have activity against pathogens and herbivores, such as alkaloids, steroids, terpenoids, peptides, polyketones, flavonoids, quinols, phenols, chlorinated compounds, and volatile organic compounds (Kaur, S., Samota, M. K., et al., (2022).

## Conclusion

The fact that there is no standard method for early warning and forecasting of the current climate change. Natural calamities such as intense rainfall, droughts during specific seasons, high temperatures, and others necessitate extreme weather conditions. It is imperative to understand and harness the potential of endophytes for developing remedies for frequent extreme weather events, which pose a significant threat to agricultural productivity. As a result of their ability to enhance nutrient uptake, endophytes support plant growth. They also protect against abiotic and biotic stresses such as diseases, pests, droughts, and salinity. Additionally, volatile organic molecules, quinols, phenols, alkaloids, steroids, terpenoids, peptides, polyketones, and flavonoids were generated. Furthermore, endophytes assist in the synthesis of hormones within plants, including gibberellins, auxins, and cytokinins, which are essential for regulating various growth and developmental processes. By unlocking the intricate mechanisms of endophyte-plant interactions, researchers can pave the way for innovative solutions to mitigate the impacts of extreme weather events on agricultural systems, thereby ensuring food security in the face of climate change.

## References


1. Card S, Johnson L, Teasdale S, Caradus J. 2016. Deciphering endophyte behavior: the link between endophyte biology and efficacious biological control agents. *FEMS Microbiol Ecology*. Aug; 92(8):19.
2. Chitnis VR, Suryanarayanan TS, Nataraja KN, Prasad SR, Oelmüller R, Shaanker RU. Fungal endophyte-mediated crop improvement: the way ahead. Front Plant Sci. 2020; 11:1588.
3. Dowling, N.G., S.M. Greenfield and K.S. Fisher, 1998. Sustainability of Rice in the Global Food System. 1 Edn. International Rice Research Institute. Los Banos, Philippines, pp: 404.
4. FAO (2021) World food situation: FAO cereal supply and demand brief. http://www.fao.org/worldfoodsituation/csdb/en/. Accessed 6 Aug 2021
5. Ganie, S.A., Karmakar, J., Roychowdhury, R., Mondal, T.K. and Dey, N., 2014. Assessment of genetic diversity in salt-tolerant rice and its wild relatives for ten SSR loci and one allele mining primer of salT gene located on 1st chromosome. *Plant systematics and evolution*, *300*, pp.1741-1747.
6. Jaroszuk-Ściseł J, Kurek E, Trytek M. 2014. Efficiency of indoleacetic acid, gibberellic acid, and ethylene synthesized in vitro by fusarium culmorum strains with different effects on cereal growth. Biologia. 69(3):281–292.
7. Kamran, M.; Imran, Q.M.; Ahmed, M.B.; Falak, N.; Khatoon, A.; Yun, B.-W. Endophyte-Mediated Stress Tolerance in Plants: A Sustainable Strategy to Enhance Resilience and Assist Crop Improvement. *Cells* **2022**, *11*, 3292.
8. Khan AL, Hussain J, Al-Harrasi A, Al-Rawahi A, Lee IJ. 2015. Endophytic fungi: resource for gibberellins and crop abiotic stress resistance. Crit Rev Biotechnol. Mar; 35(1):62–74.
9. Latz MAC, Jensen B, Collinge DB, Jorgensen HJL. 2018. Endophytic fungi as biocontrol agents: elucidating mechanisms in disease suppression. *Plant Ecol Divers. Nov*; 11(5–6):555–567. Kaddes A, Fauconnier ML, Sassi K, Nasraoui B, Jijakli MH. 2019. Endophytic fungal volatile compounds as a solution for sustainable agriculture.Molecules.Mar; 24 (6):16.

10. Phurailatpam, L. and Mishra, S., 2020. Role of plant endophytes in conferring abiotic stress tolerance. *Plant Ecophysiology and Adaptation under Climate Change: Mechanisms and Perspectives II: Mechanisms of Adaptation and Stress Amelioration*, pp.603-628.
11. Rana KL, Kour D, Kaur T, Devi R, Yadav AN, Yadav N, Dhaliwal HS, Saxena AK. 2020. Endophytic microbes: biodiversity, plant growth-promoting mechanisms and potential applications for agricultural sustainability. Antonie Van Leeuwenhoek *International Journal of General and Molecular Microbiology*. Aug; 113(8):1075–1107.
12. Yadav, A.N. Plant microbiomes for sustainable agriculture: Current research and future challenges. Plant. Microb. Sus. Agri. 2020, 475–482
13. Parry, M., Rosenzweig, C., Iglesias, A., Fischer, G., and Livermore, M. (1999). Climate change and world food security: a new assessment. Global Environ. Change. 9, 51–67. doi: 10.1016/S0959-3780(99)00018-7
14. Alam, Md Mahmudul, Mohd Toriman, Chamhuri Siwar, Rafiqul Molla, and Basri Talib. "The impacts of agricultural supports for climate change adaptation: farm level assessment study on paddy farmers." *Alam, MM, Mohd Ekhwan, T., Siwar, C., Molla, RI, and Talib, B* (2011): 178-182.
15. Wassmann, R. (2009). *[Advances in Agronomy] Volume 101 || Chapter 2 Climate Change Affecting Rice Production., (), 59–122.*
16. Bartels, Dorothea; Sunkar, Ramanjulu (2005). *Drought and Salt Tolerance in Plants. Critical Reviews in Plant Sciences, 24(1), 23–58.*
17. S. Negrão , B. Courtois , N. Ahmadi , I. Abr eu , N. Saibo & M. M. Oliveira mmolive@it qb.unl.pt (2011) Recent Updates on Salinity Stress in Rice: From Physiological to Molecular Responses, Critical Reviews in Plant Sciences, 30:4, 329377.
18. Stuart J Roy; Elise J Tucker; Mark Tester (2011). *Genetic analysis of abiotic stress tolerance in crops., 14(3), 232–239.*
19. García-Latorre, C., Rodrigo, S., Santamaría, O. (2021). Endophytes as Plant Nutrient Uptake-Promoter in Plants. In: Maheshwari, D.K., Dheeman, S. (eds) Endophytes: Mineral Nutrient Management, Volume 3. Sustainable Development and Biodiversity, vol 26. Springer, Cham. https://doi.org/10.1007/978-3-030-65447-4_11
20. Aleynova, Olga A., and Konstantin V. Kiselev. "*Interaction of Plants and Endophytic Microorganisms*: Molecular Aspects, Biological Functions, Community Composition, and Practical Applications." *Plants* 12, no. 4 (2023): 714.
21. Indira, Gajjela & Chandrakanth, Alladi & Ojre, Anjali & Kanna, T & Verma, Archana. (2023). Sustainable Agriculture Practices for Promoting Soil Health: A Crucial Paradigm for Environmental Resilience. 4. 136-139.
22. Kaur, S., Samota, M. K., Choudhary, M., Choudhary, M., Pandey, A. K., Sharma, A., & Thakur, J. (2022). How do plants defend themselves against pathogens-Biochemical mechanisms and genetic interventions. *Physiology and molecular biology of plants: an international journal of functional plant biology*, *28*(2), 485–504
23. Fadiji AE and Babalola OO (2020) Elucidating Mechanisms of Endophytes Used in Plant Protection and Other Bioactivities with Multifunctional Prospects. Front. Bioeng. Biotechnol. 8:467.
24. Singh, Vivek Kumar, and Awanish Kumar. “Secondary metabolites from endophytic fungi: Production, methods of analysis, and diverse pharmaceutical potential.” *Symbiosis (Philadelphia, Pa.)*, 1-15. 8 Jun. 2023.
25. Pandey, Veena, Mohammad W. Ansari, Suresh Tula, Sandep Yadav, Ranjan K. Sahoo, Nandini Shukla, Gurdeep Bains et al. "Dose-dependent response of Trichoderma harzianum in improving drought tolerance in rice genotypes." *Planta* 243 (2016): 1251-1264.
26. Fan, Di, and Donald L. Smith. "Mucilaginibacter sp. K improves growth and induces salt tolerance in nonhost plants via multilevel mechanisms." *Frontiers in Plant Science* 13 (2022): 938697.
27. Morelli, Massimiliano, Ofir Bahar, Kalliope K. Papadopoulou, Donald L. Hopkins, and Aleksa Obradović. "Role of endophytes in

plant health and defense against pathogens." *Frontiers in Plant Science* 11 (2020): 1312.

28. Silva, Geraldo H., Helder L. Teles, Henrique C. Trevisan, Vanderlan da S. Bolzani, Maria Young, Ludwig H. Pfenning, Marcos N. Eberlin, Renato Haddad, Claudio M. Costa-Neto, and Ângela R. Araújo. "New bioactive metabolites produced by Phomopsis cassiae, an endophytic fungus in Cassia spectabilis." *Journal of the Brazilian Chemical Society* 16 (2005): 1463-1466.
29. Suebrasri, Thanapat, Apisara Somteds, Hiroyuki Harada, Somdej Kanokmedhakul, Sanun Jogloy, Jindarat Ekprasert, Saisamorn Lumyong, and Sophon Boonlue. "Novel endophytic fungi with fungicidal metabolites suppress sclerotium disease." *Rhizosphere* 16 (2020): 100250.
30. Colombo, Elena Maria, Andrea Kunova, Cristina Pizzatti, Marco Saracchi, Paolo Cortesi, and Matias Pasquali. "Selection of an endophytic Streptomyces sp. strain DEF09 from wheat roots as a biocontrol agent against Fusarium graminearum." *Frontiers in Microbiology* 10 (2019): 2356.
31. Morelli, Massimiliano, Ofir Bahar, Kalliope K. Papadopoulou, Donald L. Hopkins, and Aleksa Obradović. "Role of endophytes in plant health and defense against pathogens." *Frontiers in Plant Science* 11 (2020): 1312.
32. Samain, Erika, Thierry Aussenac, and Sameh Selim. "The effect of plant genotype, growth stage, and Mycosphaerella graminicola strains on the efficiency and durability of wheat-induced resistance by Paenibacillus sp. Strain B2." *Frontiers in plant science* 10 (2019): 587.
33. Ganley, Rebecca J., Richard A. Sniezko, and George Newcombe. "Endophyte-mediated resistance against white pine blister rust in Pinus monticola." *Forest Ecology and Management* 255, no. 7 (2008): 2751-2760.
34. Cohen, Ana C., Claudia N. Travaglia, Ruben Bottini, and Patricia N. Piccoli. "Participation of abscisic acid and gibberellins produced by endophytic Azospirillum in the alleviation of drought effects in maize." *Botany* 87, no. 5 (2009): 455-462.
35. Reinhardt, Érica, Patrícia L. Ramos, Gilson P. Manfio, Heloiza R. Barbosa, Crodowaldo Pavan, and Carlos A. Moreira-Filho. "Molecular characterization of nitrogen-fixing bacteria isolated from Brazilian agricultural plants at São Paulo state." *Brazilian Journal of Microbiology* 39 (2008): 414-422.
36. Vargas, Livia, Ailton B. Santa Brigida, Jose P. Mota Filho, Thais G. de Carvalho, Cristian A. Rojas, Dries Vaneechoutte, Michiel Van Bel, et al. "Drought tolerance conferred to sugarcane by association with Gluconacetobacter diazotrophicus: a transcriptomic view of hormone pathways." *PLoS One* 9, no. 12 (2014): e114744
37. Jiao, Jian, Yaner Ma, Sha Chen, Chonghuai Liu, Yuyang Song, Yi Qin, Chunlong Yuan, and Yanlin Liu. "Melatonin-producing endophytic bacteria from grapevine roots promote the abiotic stress-induced production of endogenous melatonin in their hosts." *Frontiers in Plant Science* 7 (2016): 1387.
38. Chen, Chaoqiong, Kaiyun Xin, Hao Liu, Juanli Cheng, Xihui Shen, Yao Wang, and Lei Zhang. "Pantoea alhagi, a novel endophytic bacterium with ability to improve growth and drought tolerance in wheat." *Scientific Reports* 7, no. 1 (2017): 41564.
39. Jatan, Ram, Puneet Singh Chauhan, and Charu Lata. "Pseudomonas putida modulates the expression of miRNAs and their target genes in response to drought and salt stresses in chickpea (Cicer arietinum L.)." *Genomics* 111, no. 4 (2019): 509-519.
40. Shrivastava, Pooja, and Rajesh Kumar. "Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation." *Saudi journal of biological sciences* 22, no. 2 (2015): 123-131.