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Alleviation of Salinity Stress by Rhizobial and Passenger Endophytes

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Soil salinity is one of the major abiotic factor limiting the agricultural productivity of various field crops. High salt concentrations in soil adversely affect growth of plants, nutrient uptake, and overall health of various crops. In response to this challenge, several research has been increasingly focused on biological approaches to reclaim salinity stress, including the use of endophytes. Among these, Rhizobial Endophytes (RE) and Passenger Endophytes (PE) have shown promising potential in enhancing plant the resilience towards salinity stress. This study provides a comprehensive overview of how these endophytes contribute to alleviating the salinity stress in plants.

Salinity Stress: An Overview

The characteristics of soil, which provides biological niches for microbes, plants, and animals, determines the natural biodiversity. Salt stress negatively affects soils fertility, which has a significant impact on agriculture. Saline soil have a 15% exchangeable sodium content and a root zone electrical conductivity (EC) of greater than 4 dSm^{-1}. These are caused by high concentrations of certain ions in the soil solution, including sodium, calcium, magnesium, chloride, sulphate, carbonate, and bicarbonate. Some of the processes that lead to soil salinization include rainfall, soil additives, rock weathering, soluble fertilizers, saline irrigation water, and capillary rise of salt water and saline groundwater. These practices aggravate salt stress in agriculture by accumulating salt in the soil profile, which has an adverse effect on crops. Understanding the effects of salt stress on crops is crucial for developing effective management strategies and raising agricultural productivity.

Mechanism of salinity

The soil salinity is majorly created by four different mechanisms which include osmotic stress, ion toxicity, nutrient imbalance and oxidative stress. Higher amount of salt in the soil leads to high osmotic pressure, which makes plants difficult to absorb water. This results in reduced turgor pressure and dehydration. Higher concentrations of sodium (Na^+) and chloride (Cl^-) disrupts cellular functions and enzyme activities and can be toxic to plants. Excess amount of salt interferes with the uptake of essential nutrients like potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}), leading to their deficiencies and increases the stress. Elevated levels of salt can generate reactive oxygen species (ROS), thereby causing oxidative damage to cells and tissues.

Effect of soil salinity in the production of agricultural crops

Soil salinity affects several physiological systems, which substantially reduces the agricultural productivity. Osmotic stress caused by high salt levels makes it difficult for plants to absorb water, which can impede the establishment of seedlings and delay or reduces the seed germination capacity. In addition to impairing root development and function, this stress restricts the absorption of water and nutrients. As a result, the germination speed of crops are affected and the crops grow more slowly, and perform less photosynthesis activity, and absorb fewer nutrients. These disturbances together affects the plant biomass production and yield, which affects the crop production as a whole.

Alleviation of Salinity Stress by Rhizobial Endophytes (RE) and Passenger Endophytes (PE)

Rhizobial Endophytes (RE) and Passenger Endophytes (PE) have emerged as a promising biological tool to mitigate the adverse effects of soil salinity. These endophytes, which reside within the plant tissues, can enhance plant resilience through various mechanisms without causing any harm to the host plant. Rhizobial Endophytes, specifically those belonging to the genus *Rhizobium*, plays an important role in alleviating salinity stress through various mechanisms. These bacteria contribute to osmotic adjustment by producing osmolytes such as proline and glycine betaine. These osmo-protectants help the plants to maintain cell turgor pressure and provide protection against osmotic stress. Additionally, RE enhances ion homeostasis by regulating the uptake and transport of beneficial ions like potassium and reducing the accumulation of toxic sodium ions in plant tissues. They also improves antioxidant defense mechanisms of plant by increasing the production of antioxidant enzymes such as, peroxidase, super oxide dismutase and catalase, thus mitigating the oxidative stress. Furthermore, RE also improves the water use efficiency by enhancing the root growth and water uptake under saline stress. The amount of plant growth promoting substances like auxins and cytokinins, which are essential for stress response and root growth, can be altered by these bacteria. These strategies performed by the RE aids plants in overcoming the negative effects of soil salinity.

Passenger Endophytes, which comprise of a variety of bacterial and fungal species, also mitigate the effects of salt stress by a number of different mechanisms. Salt-induced nutrient imbalances are balanced by these endophytes which improves the nutrient absorption by releasing essential nutrients from the soil and increasing their availability to plants. They also affect plant stress hormone production, such ABA (abscisic acid) which plays a crucial role in stress responses. Furthermore, some PE generate growth-promoting compounds and antioxidants as secondary metabolites that prevents the plants from the effects of salinity. Certain bacterial (e.g., *Bacillus* spp.) and fungal endophytes (e.g., *Penicillium* spp.) have been shown to enhance plant growth under saline conditions. These endophytes contribute to stress alleviation by improving root architecture, increasing nutrient uptake, and enhancing overall plant health.

Application of RE and PE for enhancing plant production

By incorporating these endophytes into crop management techniques, crops can be tailored to enhance their productivity. Crops can be made to tolerate higher salinity by inoculating seeds or soil with these beneficial endophytes. The acts as the alternative for chemical ferilizers and strengthens the soil health and paves a way for sustainable agriculture. In future, more studies are required to understand the specific processes by which RE and PE alleviate the salt stress. Gaining knowledge about how they interact with soil microbiome and plant physiology can help determine how successful they are.

Conclusion

Salinity stress can be mitigated by using rhizobial and passenger endophytes in a promising way. These endophytes boost antioxidant defenses, osmotic adjustment, and ion homeostasis, which increase plant growth and resistance in saline environments. The use of RE and PE into agricultural methods has the potential to greatly improve crop yield and sustainability in salinity affected areas.

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