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Modulating reactive oxygen species and ion homeostasis for combined salt and cadmium stress tolerance in *Brassica campestris*: The role of beneficial microbes

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ABSTRACT

The land areas and crop species adversely impacted by salinity and heavy metals are growing rapidly. Current research indicates that plant growth-promoting microorganisms offer an environmentally friendly option for improving physiological and biochemical processes in plants growing under stress conditions. The aim of the present study was to investigate the potential mitigation of simultaneous salinity and cadmium (Cd) stress in rapeseed (*Brassica campestris* cv. BARI Sarisha-17) by the application of *Azospirillum* sp. (Az), phosphate solubilizing bacteria (PSB), potassium mobilizing bacteria (KMB), and vesicular arbuscular mycorrhiza (VAM). Seeds were treated with PSB or KMB prior to sowing, whereas Az, PSB, KMB, or VAM were added as supplements during soil preparation. At 21 days after sowing, the plants were treated with a combination of salt (100 mM NaCl) and Cd (0.25 mM $CdCl_2$), with several applications at 7-day intervals. The combination of salt and Cd stress decreased plant growth and biomass, relative water content, and photosynthetic pigment levels, while also increased electrolyte leakage, lipid peroxidation, and the generation of excess reactive oxygen species (ROS). Salt and Cd stress also impaired plant ion balances of sodium, potassium and nitrate, antioxidant defenses, and glyoxalase system activity. Application of Az, PSB, or KMB restored these parameters to unstressed levels by facilitating the scavenging of ROS, maintaining water status, restoring ion balances, enhancing plant antioxidant defenses, and increasing glyoxalase enzyme activity, while reducing methylglyoxal toxicity and improving photosynthetic activity. The application of KMB was the most effective; however, all microbe supplementations showed the ability to alleviate the damage caused by stress in rapeseed. These findings highlight the ability of soil microorganisms with plant growth-promoting properties to improve the physiological and biochemical functions of rapeseed under Cd and salt stress.

1. Introduction

Climate change imposes various environmental stresses on plants, animals, and living organisms. Extreme temperatures, soil salinity, drought, nutrient deficits, and heavy metal accumulation are the most prevalent environmental or abiotic stresses that threaten plant life (Zhang et al., 2022). Among these factors, soil salinity and the buildup of heavy metals have diverse detrimental effects that hinder agricultural production. Notably, anthropogenic activities continue to increase the Earth's land mass threatened by soil salinity and heavy metal accumulation. Industrialization has led to cadmium (Cd) becoming one of the most destructive heavy metals present in soil, even at low concentrations, as Cd is highly mobile and readily absorbed by plants from the soil. In plant tissues, Cd reduces photosynthetic pigment biosynthesis, thereby inhibiting photosynthesis (Li et al., 2015).

Soil salinity is another global risk that can create food insecurity and alter sustainable agriculture systems. At present, salinity issues affect over 33 % of irrigated and 20 % of cultivated lands (Mukhopadhyay et al., 2020). Crop production is also significantly reduced by salinity stress, which renders plants more susceptible to disease, increases ion

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