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Article

Enhancement of Morphological and Physiological Performance of *Zea mays* L. under Saline Stress Using ZnO Nanoparticles and 24-Epibrassinolide Seed Priming

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Abstract: Salinity is one of the most devastating environmental factors limiting crop productivity worldwide. Therefore, our study investigates the effect of seed priming with zinc oxide nanoparticles (ZnO NPs: 0, 50, and 100 mg L^{-1}), 24-epibrassinolide (EBL: 0.0, 0.2, and 0.4 µM), and their combined treatments on maize (*Zea mays* L.) grown with different levels of saline stress (i.e., control, 5, 10 dS m^{-1}) under semi-controlled conditions. Higher saline stress (10 dS m^{-1}) negatively influenced the growth traits, physiological attributes, and elemental (i.e., Zn and K) uptake for both roots and shoots of maize, whereas it increased Na^+ accumulation and Na^+/K^+ ratio in comparison to other treatments. However, seed priming with ZnO NPs and EBL as well as their combinations showed amelioration of the detrimental effects of saline stress on the growth and physiological and biochemical performance of maize. In general, seed priming with combined treatments of ZnO NPs and EBL were significantly more effective than either ZnO NPs or EBL as individual treatments. A combination of 100 mg L^{-1} ZnO NPS + 0.2 µM EBL resulted in the highest values of root length, root surface area, stem diameter, relative leaf water contents, total chlorophyll, net rate of photosynthesis, zinc accumulation, and K^+ uptake, while it resulted in the lowest Na^+ and Na^+/K^+ ratio, especially under the highest saline-stress treatment. Thus, we concluded that seed priming with combined ZnO NPs and EBL can effectively mitigate the saline-stress-mediated decline in the morphological, physiological, and biochemical traits of maize.

Keywords: saline stress; maize; seed priming; nanoparticles; EBL

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1. Introduction

Saline stress is one of the major abiotic stresses which can limit the agricultural productivity of agronomic crops [1]. More than 6% of global land is already salt-affected, and this percentage is expected to rise in the coming decades. This occupies about 20% of the total cultivated land, out of which approximately 50% is irrigated [2–4]. Salinity stress can significantly affect the performances of agricultural plants; however, the mechanism of its action could be divided into two major processes. Firstly, osmotic stress, in which it can limit water absorption by creating a negative water potential in the rhizosphere and, hence, can inhibit plant growth. Secondly, ionic toxicity; once it enters the transpiration stream, the excessive Na^+ and Cl^- damage the plant cellular structures and alter the molecular composition, resulting in the impairment of homeostasis, physiological processes, cell division, growth, and production of primary and secondary metabolites [5,6]. Saline stress can disturb the photosynthetic process at different levels, such as (a) at the molecular level by decreasing the production of photosynthetic pigments, dysfunction of proteins involved, and denaturation of enzymes and structural molecules, (b) at the stomatal level