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Exogenous Application of Zinc Oxide Nanoparticles Improved Antioxidants, Photosynthetic, and Yield Traits in Salt-Stressed Maize

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Abstract: Salinity is one of the most threatening abiotic stresses to agricultural production, alarmingly expanding both through natural salinization phenomena and anthropogenic activities in recent times. The exploration of sustainable and eco-friendly strategic approaches for mitigating the negative impact of salinity on food crops is of vital importance for future food security. Therefore, our study aimed to evaluate zinc oxide nanoparticles (ZnO-NPs) as potent salinity mitigators in maize (*Zea mays* L.). Three ZnO-NPs foliar treatments (i.e., 0, 50, and 100 mg/L) were applied 40, 55, and 70 days after sowing on maize plants exposed to continuous salinities of 0 mM NaCl (S0), 60 mM NaCl (S1), and 120 mM NaCl (S3) in a semi-automated greenhouse facility. Results showed that the highest salinity (i.e., 120 mM NaCl) significantly affected plant growth attributes, physiological performance, nutrient profiles, antioxidant activity, plant yield, and yield-contributing characteristics of maize plants. Thus, 120 mM NaCl resulted in −53% number of grains per cob (NG), −67% grains weight per cob (GW), −36% 100-grains weight (HGW), and −72% grain yield per plant (GY) compared to controls. However, foliar treatment of maize plants with ZnO-NPs successfully mitigated salinity and significantly improved all studied parameters, except transpiration rate (TR) and intrinsic water use efficiency (iWUE). Foliar application of 100 mg/L of ZnO-NPs alleviated NG, GW, HGW, and GY by 31%, 51%, 13%, and 53%, respectively. Furthermore, principal component analysis (PCA) and Pearson's correlation further strengthened the significance of ZnO-NP application as salinity mitigators.

Keywords: ZnO nanoparticles; crop tolerance; productivity; abiotic stress; *Zea mays* L.

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1. Introduction

Over 20% of irrigated lands are salt-affected soils, which may expand up to 50% by 2050 [1–4]. Anthropogenic activities, including excessive use of agrochemicals, industrial waste, and unsustainable agricultural practices are further aiding the development of soil salinity [3,5,6]. Soil salinity is also impacting ecosystems' natural balance, biodiversity, biochemicals in soil, sustainable food security, and the socio-economic health of farmers' communities in more than 120 countries across the globe [4,7]. The conjunction of growing food demand, urbanization, land degradation, climate change, and reduced availability of freshwater for irrigation further complicates the problem and compels farmers to use marginal lands such as saline soils and poor-quality irrigation water to enhance net agricultural production [1]. Hence, using sustainable approaches to mitigate salinity has become an important target for agronomic crops that are grown under environmental stresses.