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Effect of Seed Priming with ZnO Nanoparticles and Saline Irrigation Water in Yield and Nutrients Uptake by Wheat Plants †

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Abstract: Salinity is one of the major abiotic stresses that affect crop production in arid and semiarid areas. The nano-priming can be applied to improve the seeds germination and seedling establishment and enhance plant growth in addition to improving resistance to abiotic stresses. A pot experiment was conducted to study the influence of seed priming with (50 mg L^{-1}) ZnO nanoparticles (particle size < 50 nm) and irrigation with saline water on the yield and uptake of some nutrients (N, P, K, and Zn) by durum wheat variety (*Triticum Durum* L., cv. Acsad1105). Wheat variety was grown in calcareous soil under four levels of saline irrigation water (0.52, 4.42, 6.84 and 9.3 dS m^{-1}). Increasing water salinity caused a gradual and remarkable decrease in the grain yield, where the reduction was the highest (42.8%) at the higher salinity level (9.13 dS m^{-1}). Seed priming with ZnO NPs increased the grain yield by 36.2, 24.1, 13.2 and 5.6% for the investigated salinity levels, respectively, compared with non-primed seeds. The uptake of macronutrients (N, P and K) by both the straw and grains was significantly increased by increasing the salinity level up to 6.84 dS m^{-1}, particularly in the primed seeds. On the other hand, Zn uptake was significantly decreased in the two treatments with an increasing salinity level of irrigation water. However, field studies may further enhance the mechanistic understanding of the pertinence of NPs in seed priming and salinity-tolerant plants.

Keywords: durum wheat; salinity stress; seed priming; ZnO NPs

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1. Introduction

Wheat is a moderately tolerant plant to salinity stress. It is considered, drought, as the major abiotic stress that affects the production capacity in arid and semiarid areas. Seed germination and seedling establishment are the most sensitive stages to salinity. Salt stress can adversely affect seed germination and the initial seedling growth via both the osmotic effect and ionic toxicity, which will induce oxidative stress [1]. It is a well-known fact that world resources of freshwater are getting exhausted through the increasing demand to meet the ever-increasing requirements of the world population. Therefore, the use of low water quality, e.g., groundwater, drainage water and treated seawater, should be considered as complementary sources for agricultural development. Nano-priming can be applied in seeds to provide protection during storage and improve germination and germination synchronization.

The use of nanotechnology for seed priming is a new area of research, although studies have already shown promising results [2,3]. Seed priming with nanomaterials can promote seed germination and enhance initial vegetative growth and biochemical characteristics in various plant species [4]. The treatment is simple and cost-effective. Primed seeds can rapidly absorb and renovate the seed metabolism, resulting in a higher germination rate and decreasing the intrinsic physiological non-uniformity in germination [5,6]. Seed priming can also improve plant growth, development, and the production capacity of crops [7,8]. Different methods are used to apply the zinc oxide (ZnO) nanoparticles on wheat, like foliar spray, soil mixing and seed priming methods [9]. ZnO nanoparticles at low concentrations promote the production of antioxidant enzymic and non-enzymic molecules, phytohormones and the overexpression of new water channels, thereby improving the absorption of water and nutrients with ZnO nanoparticles seed priming which can help the initial growth of seedlings [10]. New studies showed that priming of wheat seeds with zinc oxide nanoparticles (50 mg L^{-1}) and after 20 days of recovery of the plants being exposed to salt stress (200 mM NaCl) for 10 days reduced the concentration of Na^+ and increased water uptake [11]. However, when plants were exposed to salt stress, the nano-ZnO primed plants had significantly higher photosynthetic, stomatal conductance and transpiration rates compared with the non-primed plants [12]. The current work had the objective to study the influence of seed priming with ZnO nanoparticles and saline water irrigation (drainage water) on yield and nutrient uptake (N, P, K, and Zn) of durum wheat variety (Acsad1105) grown in calcareous soil.

2. Materials and Methods

Two varieties of wheat seeds (*Triticum Durum* L., cv. Acsad1105) were used in this experiment, the first one was left without any treatment (non-primed seed) and the second group was primed with 50 ppm ZnO nanoparticles for 4 h before sowing. The ZnO nanoparticles (particle size < 50 nm) were obtained from Begbroke Directorate, University of Oxford Science Park, Oxford OX5 1PF, UK, and both groups were used in a pot experiment under four levels of saline water. The pots were filled with 10 kg calcareous soil (Sandy loam, 24.5% $CaCO_3$ and EC: 2.27 dS m^{-1}) collected from Al-Tabny village in the west of Deir Ezzor Governorate, Syria. The primed and non-primed wheat seeds were sown separately in each pot. The seedlings were irrigated with tap water (W1: 0.52 dS m^{-1}) as a control and three levels of saline drainage water (W2: 4.42, W3: 6.82 and W4: 9.13 dS m^{-1}). After 160 days from planting, plants were harvested and the grain yield per pot, straw per pot and the 1000-kernel weight were recorded. Representative plant samples were digested for N, P, K and Zn determination. The IBM SPSS software (Version 25.0) was used to statistically analyze data at a 5.0% probability ($p \leq 0.05$).

3. Results and Discussion

The results revealed that increasing the salinity of irrigation water in the primed and non-primed seeds significantly ($p < 0.05$) decreased all the studied traits, but the reduction was significantly lower ($p < 0.05$) in ZnO NPs primed seeds (Figure 1a). However, increasing water salinity up to 4.42, 6.84 and 9.13 dS m^{-1} caused a remarkable decline in the grain yield of the non-primed wheat seeds by 12.9, 20.4 and 42.8%, respectively, meanwhile the priming of seeds with 50 ppm ZnO NPs increased grain yield by 36.2, 24.1, 13.2 and 5.6% under saline irrigation water of 0.52, 4.42, 6.84 and 9.3 dS m^{-1}, respectively, compared with the non-primed seeds (Figure 1b).

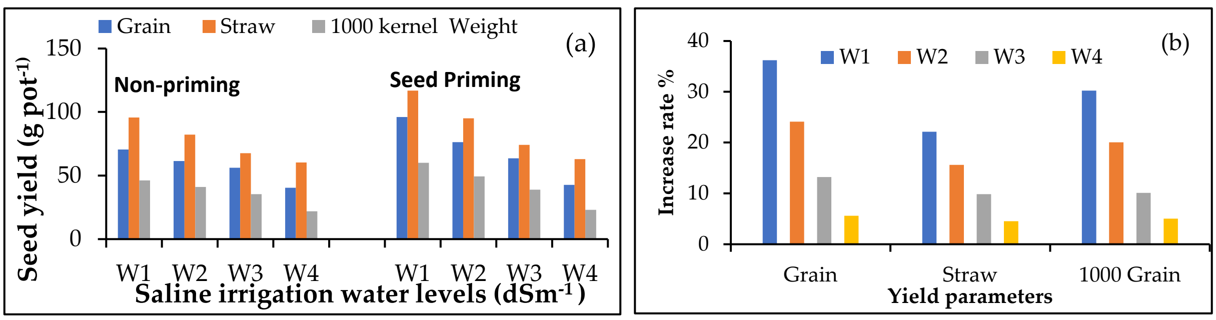

Figure 1. Effect of saline irrigation water and seed priming on seed yield (g pot^{-1}) of durum wheat plants (**a**), and increase rate in yield parameters due to seed priming(**b**).

Concerning the straw yield and 1000-kernel weight, the obtained data showed a similar trend as previously shown for grain yield. Both treatments had significant differences ($p < 0.05$) between primed seeds over non-primed ones (Figure 1b). Macronutrients, N, P and K uptake by grains and straw of wheat plants were significantly affected ($p < 0.05$) by salinity in both the treatments (primed and non-primed seeds) (Figure 2a,b). The maximum uptake values by grains were found to be under the W3 level. However, it has been noticed that the seed priming significantly enhanced ($p < 0.05$) the uptake of these nutrients by grain in non-primed seeds (1455, 412 and 583 mg pot^{-1}) and 1674, 467 and 647 mg pot^{-1} for N, P and K in primed seeds. A similar trend was recorded for the nutrients uptake by the straw; at the same time, the nutrient uptake was the least at the highest salinity level for both treatments. This could be attributed to the effect of higher soluble salts on decreasing the water potential gradient between the soil solution and the root cells, thereby decreasing the water flow and absorption which will adversely affect the nutrient uptake. In addition to the antagonistic effects of the higher concentration of Na^{+} and Cl^{-} on the uptake of other beneficial cations and anions.

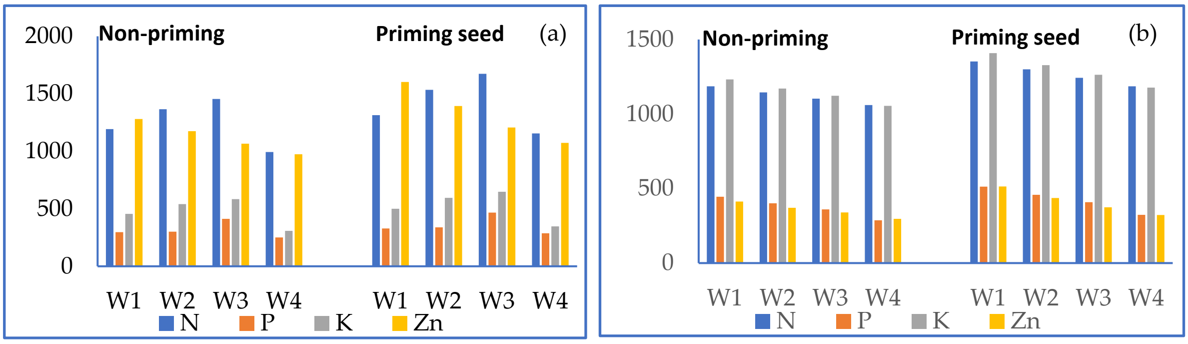

Figure 2. Effect of irrigation water salinity and seed priming on nutrients uptake (N, P, K in mg pot^{-1} and Zn in µg pot^{-1}) by grain (**a**) and straw (**b**).

On the other hand, Zn uptake (µg pot^{-1}) significantly decreased ($p < 0.05$) in both treatments with an increasing salinity level of irrigation water due to the reduction of the dry weight of wheat plants for both straw and grains. The decline was highest in the non-primed seeds compared with primed ones, thus the seed priming with ZnO NPs could improve the Zn uptake from 8 to 25% depending on the level of salinity imposed. These results agree with those obtained by Gaafar et al. (2020) [13], they found that Zn^{+2} content in soybeans was significantly decreased under salinity stress by 76% compared to control, and presoaking of soybean seeds with ZnO NPs (50 mg L^{-1}) increased Zn^{+2} content even under salinity stress 2.7-fold compared to salt treatment alone.

Excessive salinity has a detrimental effect on the growth and wheat yield by restricting nutrients uptake to extent that a deficiency takes place. This may be due to the possibility that plants grown under saline conditions utilize energy for the osmotic adjustment process at the expense of growth and development, in addition to limiting the water flow from soil to plant under saline conditions as a consequence of the decreasing water potential gradient, which will cause a remarkable decline in turgor potential and stomatal conductance (gs). However, seed priming with ZnO NPs increases the root extension and the number of effective root hairs during the early stages of wheat plant growth [14] and improved plant height, chlorophyll content, photosynthetic efficiency, tiller number and, finally, biological and grain yields. Furthermore, ZnO seed priming increases the Zn content in both leaves and seeds [15], and positively affects the growth traits in salt-stressed plants, whereas ZnO NPs stimulated natural auxin (Indole Acetic Acid) and thus activating cell division and enlargement as well as augmentation of photosynthetic pigments, organic solutes, total phenols, ascorbic acid and Zn in stressed plants [16].

4. Conclusions

Salinity stress adversely effects wheat plant growth and grain yield and yield components. However, priming seeds with ZnO nanoparticles was an effective technique to improve the performance of wheat plants, straw and seed yield under salinity stress conditions.

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Conflicts of Interest: The authors declare no conflict of interest.

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