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Proceeding Paper

The Response of Drought-Stressed Green Pea (*Pisum sativum* L.) to Boron Nanoparticle Application †

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Abstract: Maintaining pea-growing areas is becoming increasingly difficult because they are highly sensitive to environmental stresses, especially drought. Green peas (*Pisum sativum* L.) are a very important source of amino acids in the diet of humans, poultry, and livestock nutrition, as well as in crop rotation. To reduce the potential adverse effects of drought on peas, this study aimed to investigate the effects of different concentrations of boron nanoparticles (B NPs) on plants via different routes of exposure: through leaves spraying and root watering. The research was carried out in a greenhouse, 10 green pea seeds ('Respect') were sown in 10 L vegetative pots and were thinned up to 7 plants per pot after germination. When the peas reached the 39 BBCH growth stage (had 9 or more visibly extended internodes) they were foliar sprayed to full wetness (ca. 14 ± 0.5 mL plant^{-1}) or watered (100 ± 1 mL per pot) with suspensions containing different concentrations of B NPs: 0 (watered or sprayed with distilled water), 0.0125, 0.025, and 0.05 mg mL^{-1} During the 10-day drought period, low substrate moisture (30%) was maintained for peas exposed to B NPs, other plants (controls) were grown under normal substrate moisture (80%). At the end of the experiment, peas were harvested to assess the interactive effects of B NPs and drought on plants growth and enzymatic (SOD, GR, APX) and non-enzymatic (TPC, FRAP) antioxidants activity. The results showed that foliar spraying or watering at a concentration of 0.05 mg L^{-1} B NPs had a strong positive effect on pea leaf area, shoot height, fresh biomass, root length, and the number of nodules when plants grown in drought conditions. Positive effects on the activity of enzymatic (SOD, GR, APX) and non-enzymatic (TPC, FRAP) antioxidants in the pea plant were found. In general B NPs protected green peas from the adverse effects of drought stress if the appropriate concentration and application to the plant were selected.

Keywords: Boron nanoparticles; green pea; antioxidant activity; drought

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1. Introduction

Sufficient soil boron can ensure optimal crop growth, development, yield quantity and quality [1]. The effects of nanosized boron on pea seedlings have not been studied so far. However, in soybean, B NPs (0.6 mg kg^{-1}) had a positive effect on growth, yield and grain micronutrient quality under drought conditions [2]. In addition, Dimkpa and colleagues [3] demonstrated that B NPs are more effective than bulk B.

Based on these studies, we can see that the beneficial role of B NPs in green peas *(Pisum sativum* L.) is not well explored. Although peas are widely cultivated crops due to their rich source of protein, amino acids, and vitamins in the diet of humans, poultry, and livestock nutrition [4]. Legumes are also incorporated into agricultural systems to improve soil fertility, reduce the use of chemical fertilizers, and break pathogen disease cycles. Members

of the legume family form nodules on their roots where *Rhizobium* bacteria fix nitrogen from the air and thus enrich the soil with nitrogen available to plants. Thus, peas play a significant role in crop rotation and are sensitive to drought and were therefore chosen as model crops. To reduce the potential adverse effects of droughts on peas, this study aimed to investigate the effects of different concentrations of boron nanoparticles (B NPs) on plants via different routes of exposure: through leaves spraying and root watering.

2. Methods

The plants and their growth conditions were as follows: The research was carried out in a greenhouse; 10 green pea seeds ('Respect') were sown in 10 L vegetative pots and were thinned to up to seven plants per pot, after germination. When the peas reached the 39 BBCH growth stage (had nine or more visibly extended internodes), they were foliar sprayed to full wetness (ca. 14 ± 0.5 mL plant^{-1}) or watered (100 ± 1 mL per pot) with suspensions containing different concentrations of B NPs: 0 (watered or sprayed with distilled water), 0.0125, 0.025, and 0.05 mg mL^{-1}. During the 10-day drought period, low substrate moisture conditions (30%) were maintained for peas exposed to B NPs, but other plants (controls) were grown under normal substrate moisture conditions (80%). At the end of the experiment, peas were harvested to assess the interactive effects of B NPs and drought on plants growth and enzymatic (SOD, GR, APX) and non-enzymatic (TPC, FRAP) antioxidant activity.

The boron (B) NPs' preparation involved: B NPs (particle size: 100 nm; purity: 99.9%) were used for this experiment (US Research Nanomaterials, Inc., Houston, TX, USA). The NPs with concentrations of 12.5 ppm, 25 ppm, and 50 ppm were suspended in deionized water and ultrasonically dispersed for 60 min. The NPs sizes and suspension stabilities were measured using a Delsa™ Nano Submicron Particle Size (Beckman Coulter Instruments. Corporation, Fullerton, CA, USA) and Zeta Potential device (Dispersion Technology Inc., Bedford Hills, NY, USA).

3. Results and Conclusions

The results showed that foliar spraying or watering at a concentration of 0.05 mg L^{-1} B NPs had a strong positive effect on the pea leaf area, shoot height, fresh biomass, root length, and the number of nodules when the plants were grown in drought conditions. Positive effects on the activity of enzymatic (SOD, GR, APX) and non-enzymatic (TPC, FRAP) antioxidants in the pea plant were found. In general, B NPs protected green peas from the adverse effects of drought stress when the appropriate concentration and application to the plant was selected.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/IECHo2022-12516/s1.

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