Combined effects of Dielectric Barrier Discharge plasma treatment and Ag nanoparticles on Triticum Durum seed germination

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We present and discuss results of investigations on the influence of atmospheric-pressure plasma, created by a dielectric barrier discharge (DBD), on Triticum Durum wheat seeds, combined with the effect of different amounts of colloidal silver nanoparticles in aqueous solution, known for their antibacterial and antifungal properties. The plant germination rates along with plant root and stem growth have been monitored over two weeks and compared with plant features of reference seed batches.

Plasma treatments are currently intensively studied as seed processing technology for agricultural purposes [1]. Although atmospheric barrier plasma discharges are already widely used in agriculture, the collective influence concomitantly with secondary treatments still remains unknown. On the other hand, colloidal Silver nanoparticles are also extensively used in agriculture and other industries for decontamination purposes. These are widely known for their effect on microbiological organisms of various pathogenic bacterial strains [2-5]. Its addition to the germination water helps protecting the seed from the evolution of pests that can inhibit the germination process and further plant development. Several theories are proposed as to why Silver nanoparticles are highly effective in bacterial deactivation, including membrane thinning [6], acting on the respiratory chain [7] or directly on the DNA strains [8]. The toxicity of Ag nanoparticles also extends to living organisms such as aquatic life (fish) where prolonged exposure to NO_3Ag or Ag nanoparticles has a detrimental effect on overall health due to Ag particles accumulation in the lungs and liver [9,10] and must be applied with caution.

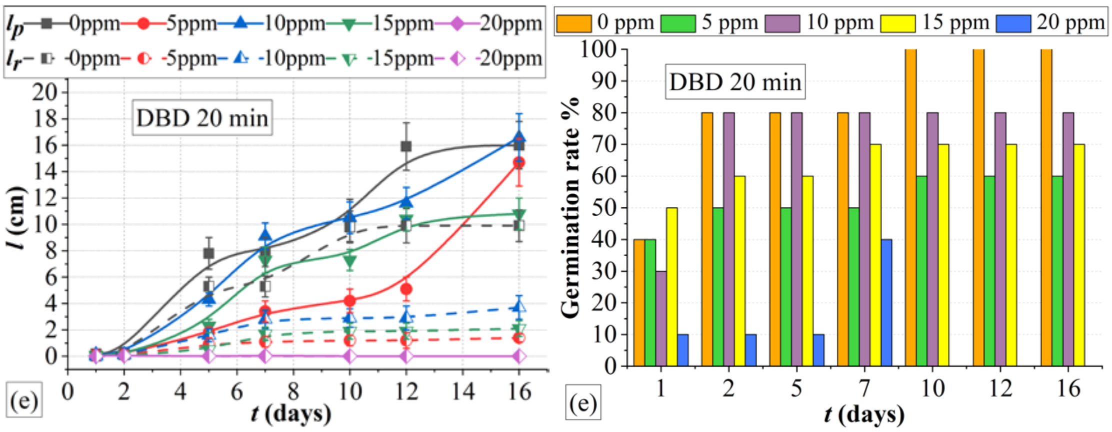

Fig. 1: Evolution rates of l_p - plant length and l_r - root length (left) and seed germination rates for 20 min DBD-treatment with increasing amounts of applied colloidal Ag concentrations (right).

Materials and Methods

A total number of 250 Triticum Durum seeds have been used in these experiments. A group of 50 untreated seeds have been kept and used as reference. The rest of 200 seeds were subjected to cold plasma treatment in a planar parallel DBD configuration with a 5 mm gap, an AC discharge at 50 Hz and 15,5 kV peak-to-peak amplitude for treatment durations of 3, 5, 10 and 20 min. In order to observe the dynamics of reactive O_2 and N_2 species in gas phase, we used the Fourier-transform infrared spectroscopy (FTIR) technique (JASCO 4700 series). During plasma exposure onto the wheat seeds, fresh air was circulated in the discharge gap and passed through the FTIR gas cell (with a light path of 100 mm). Spectra were acquired with a resolution of $r = 4$ cm^{-1}, with a wavenumber range between $n = 4400$ to 600 cm^{-1}.

Every seed batch, including the reference group, was then separated further into five equal quantities and placed into Petri dishes, where distilled water with different concentrations of colloidal Ag (0, 5, 10, 15 and 20 ppm) were added. The colloidal Silver nanoparticles with typical sizes between 20-60 nm were obtained by electrolysis in a commercial two-electrode configuration.

An JEOL JSM 6390 instrument, with a Schottky electron gun operated under 80 kV accelerating voltage at 10 µA emission current, was used in order to perform high-resolution SEM imaging and EDS spectroscopy analysis on the seeds. This allowed for both imaging and elemental mapping of the atomic species present on the seed surfaces.

Conclusion

Seed treatment by applying individual plasma treatment or in combination with different quantities of colloidal Ag have been monitored and evaluated. Generally, this has led to increased germination and higher plant size compared to reference untreated batch, where only 60% of the seeds have sprouted. The highest germination rate was recorded for a concentration of 20 ppm Ag nanoparticles with no applied DBD treatment. On the other hand, favourable for the sprouting process was also a shorter DBD treatment of 10 min cumulated with lower Ag nanoparticle concentrations of 5 to 10 ppm, where 90% germination rate was achieved. Longer DBD treatment together with high-concentration colloidal Ag has proven to inhibit plant growth, the two being not compatible.

The DBD treatment alone had a positive effect on monitored plant characteristics, while the addition of increasing amounts of colloidal Ag had an overall negative effect, due to its high toxicity.

[1] A. Waskow, *Plasma Processes and Polymers* **19** (2022) 2100152 1–22.

[2] D. Thuc, *Materials Letters* **181** (2016) 173–177.

[3] S. Sudheer Khan, *Colloids and Surfaces B: Biointerfaces* **87** (2011) 129–138.

[4] P. Logeswari, *Journal of Saudi Chemical Society* **19** (2015) 311–317.

[5] A. Miri, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* **141** (2015) 287–291;

[6] I. Sondi, *J. Colloid Interface Sci.* **275** (2004) 177–182.

[7] Q.L. Feng, *J. Biomed. Mater. Res.* **52** (2008) 662–668.

[8] J.R. Morones, *Nanotechnology* **16** (2005) 2346–2353.

[9] D Nayak, *Journal of Colloid and Interface Science* **457** (2015) 329–338.

[10] A. Bruneau, *Aquatic Toxicology* **174** (2016) 70–81.