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Effect of plasma activated water on Lettuce (Lactuca sativa) plant growth and seed germination

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Introductions: Cold plasma produced by atmospheric pressure air discharges contains a variety of gaseous reactive oxygen and nitrogen species (RONS) [1-2]. When plasma comes in contact with water, the RONS dissolve and affect the chemical composition of the water, generating plasma-activated water (PAW). The long-lived liquid RONS (O₂, H₂O₂, NO₂⁻, NO₃⁻) in the PAW may function as nutrients or as signaling molecules in plant metabolism, opening up potential uses in a variety of agricultural applications. We studied the effect of PAW generated by transient spark (TS) [1] and Fountain Dielectric Barrier Discharge (FDBD) [3] on lettuce (Lactuca Sativa) seed germination and plant growth. Tap water (TW) was used for activation by plasma and irrigation of plants in soil. Immediate measurements were taken to determine the concentrations of O₂, H₂O₂, NO₂⁻, and NO₃⁻ in the PAW after plasma activation. Different parameters of PAW including pH, Total Dissolved Solid (TDS), and Electric Conductivity (EC) are measured in this study.

Methods

1. Plasma activated water setups: A Fountain Dielectric Barrier Discharge (FDBD) reactor treats water at high flow rates, resembling a fountain. It uses a quartz tube as dielectric, copper tube as inner electrode, and copper coil as external electrode. A 10 kV 20kHz and a 24V DC power supply are used for the plasma and the water pump, respectively. The water flow rate during circulation in the reactor varied from 0.9 to 2.3 l min⁻¹ as a main process parameter in the experiments. In transient spark plasma power electrode was connected to a DC (12kV) power supply through a 10MΩ resistor. A ring as a grounded electrode is in the water. And the treatment time for transient spark treated water is 10 min/ml. The schematic diagram of the plasma systems is shown in figure 1 A,B.

2. RONS, pH, TDS, EC Measurement: All PAW parameters were performed exactly after the activation. But due to the high temperature after activation, we irrigated for 10 minutes to reach the temperature balance. The pH and temperature of each plasma-treated sample were measured using a portable pH meter (WTW 3110, Weilheim, Germany). The conductivity of the PAW samples was measured using a Digital Conductivity Meter GMH 3430. The concentration of H₂O₂ was determined using the titanium oxy-sulfate (TiO₂SO₄) assay under acidic conditions. The amounts of NO₂⁻ and NO₃⁻ were determined using Griess reagents.

Result and discussion: Temperature measurement after activation shows that temperature changes for TS in 10 minutes are more than temperature changes for FDBD in 20 minutes. Also, the pH, TDS and conductivity for TS have changed more than in FDBD. Higher nitrate, nitrite and hydrogen peroxide were produced in TW, but the amount of ozone measured in FDBD was higher. Although the amounts of active species created in TW were higher, no significant differences have been seen in lettuce growth between FDBD and TS, although compared to control TW, the difference is significant.

Conclusion: The preliminary experiments show that plasma activated water both for TS and FDBD can significantly increase the germination and plant size due to the presence of stable active species. The germination rate increase for this type of plasmas was over 20%.

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