Plasma-activated water enhances growth, antioxidant activity, and sensory quality of hydroponically grown lettuce

Adriana Mišúthová [1], Zuzana Lukačová [2], Ramin Mehrabifard [1], Zdenko Machala [1]

[1] Division of Environmental Physics, Comenius University Bratislava, Slovakia

[2] Department of Plant Physiology, Comenius University Bratislava, Slovakia

E-mail: adriana.misuthova@fmph.uniba.sk

Background

The growing global population increases the need for sustainable food production. Traditional farming relies heavily on synthetic fertilizers, especially nitrogen-based ones [1,2]. Emerging physical methods—like static magnetic fields, pulsed electric fields, and cold atmospheric plasmas—offer potential alternatives, though their effects on plants are still being studied [3,4]. One promising method is plasma-activated water (PAW), created when electrical discharges interact with water, producing reactive oxygen and nitrogen species (RONS) such as hydrogen peroxide (H_2O_2), nitrites (NO_2^-), and nitrates (NO_3^-). These components aid plant growth: H_2O_2 affects cell signaling, while NO_2^- and NO_3^- provide essential nitrogen. PAW thus offers a sustainable, eco-friendly alternative to traditional nitrogen fertilizers.

Objective

- Evaluate the effects of **seed priming** with PAW and subsequent **hydroponic cultivation in PAW-enriched Hoagland solution on lettuce.**
- Focus on plant growth, antioxidant response, and the impact of these treatments on sensory attributes, including taste, visual appearance, and aroma, assessed through a sensory evaluation.

Conclusion

⚡ PAW

↓ Smallest head & lowest fresh wight

↑↑ Highest phenolics & flavonoids

↑ SOD, APX, GR (young) G-POX (old)

💧 PAW + Priming

↑↑ Largest and most palatable plants

↑ High phenolics & flavonoids

↑ APX, GR (young) G-POX (old)

🌱 Ctrl +Priming

↑ Improved plant growth

↑ High phenolics & flavonoids

↑ Antioxidant activity (older leaves)

⚡**PAW alone** boosted antioxidant defenses but limited growth.

🌱**Priming** enhanced growth and antioxidants in older leaves.

💧 **PAW + Priming** achieved the **best balance** — vigorous growth *and* strong antioxidant activity.

Acknowledgement

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References

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[2] Sharma A 2017 International Journal for Research in Applied Science and Engineering Technology 5, 677–680.
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Results

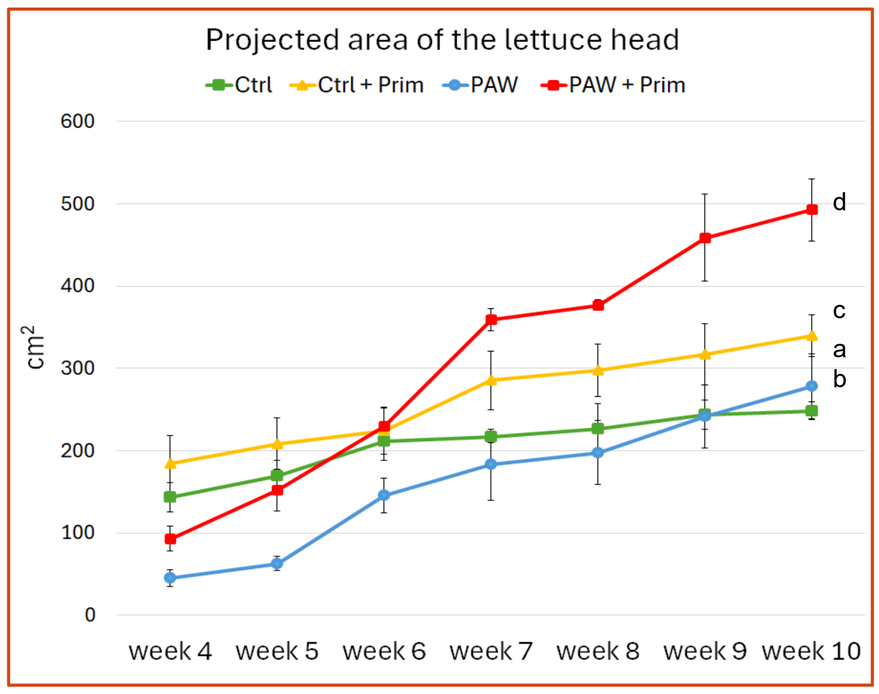


Figure 1: Projected area of the lettuce head over 4–10 weeks of cultivation. Different letters indicate statistically significant differences among treatments according to LSD test (P≤0.05).

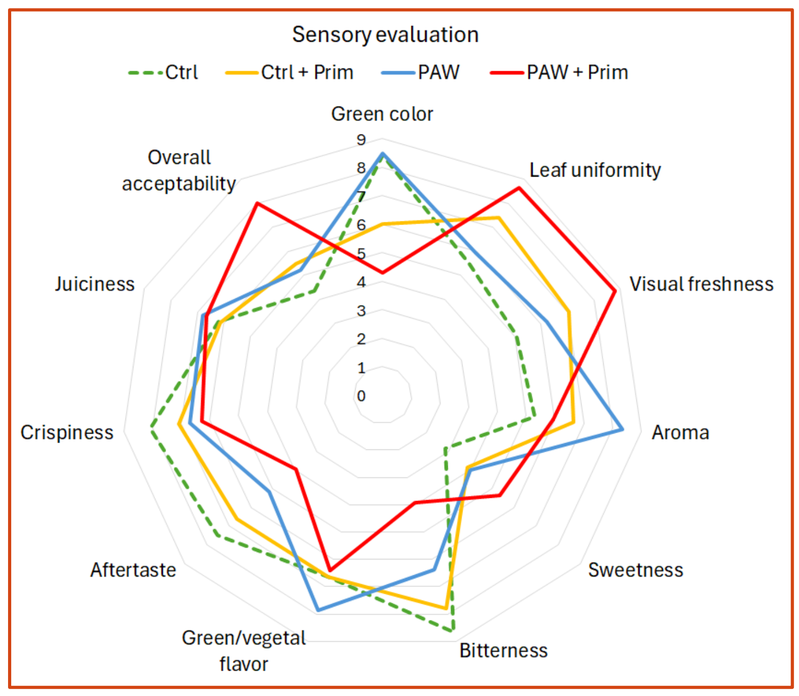


Figure 2: Sensory evaluation of lettuce after 10 weeks of cultivation.

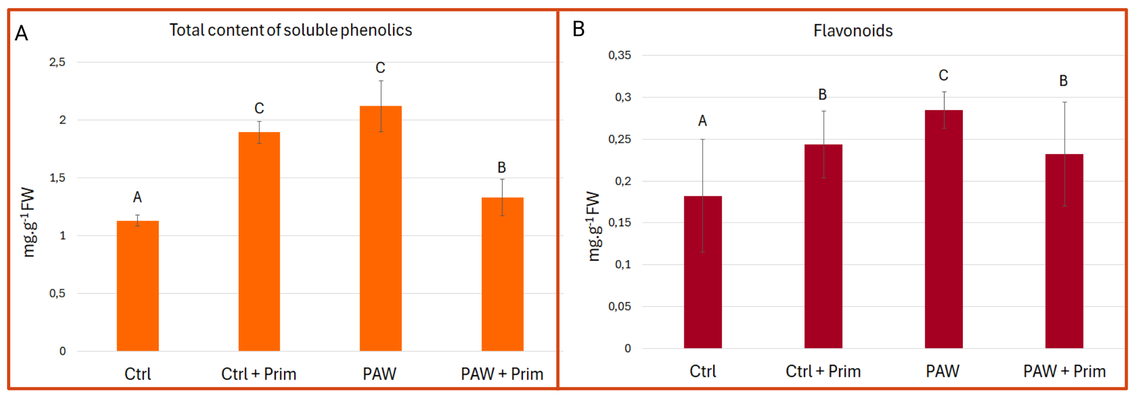
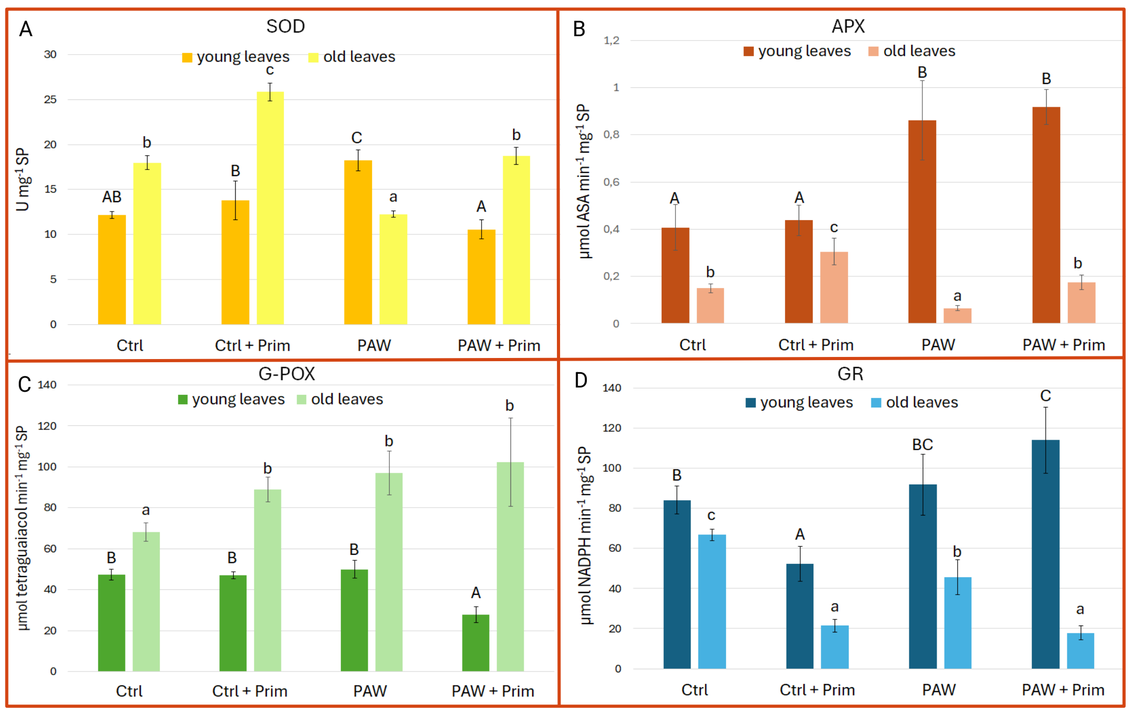


Figure 3: Total content of soluble phenolics (Galic Acid Equivalents) (A) and content of flavonoids (Quercetin) (B) in central rosette leaves lettuce plants. Different letters indicate statistically significant differences among treatments according to LSD test (P≤0.05).



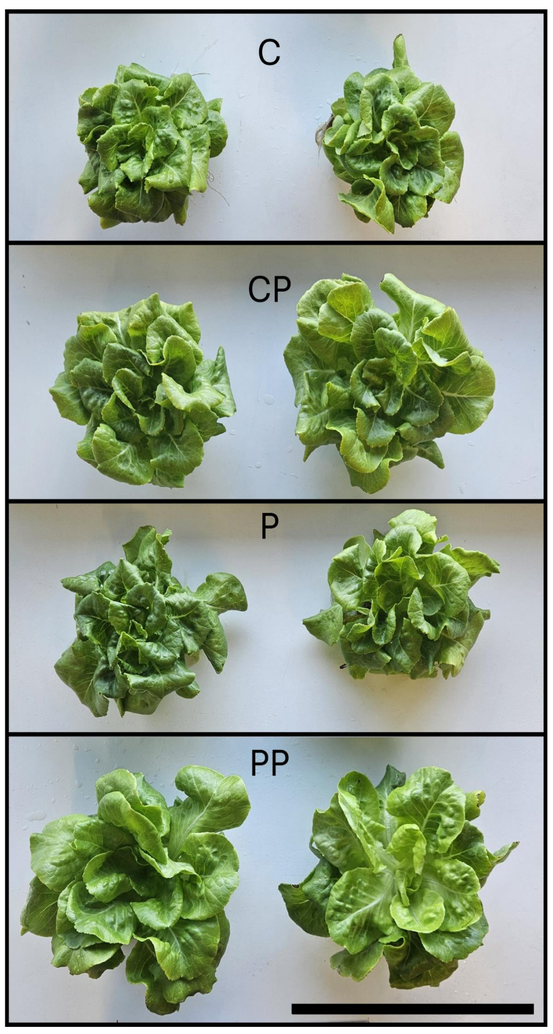


Figure 4: Overall appearance of lettuce plants after 10 weeks of cultivation. Scale bar = 30 cm.

Figure 5: Activity of SOD (A), APX (B), G-POX (C) and GR (D) antioxidant enzymes in young and old leaves of lettuce plants. Different letters indicate statistically significant differences among treatments according to LSD test (P≤0.05).

Material & Methods

Plant material

Lettuce plants (*Lactuca sativa* L.) were cultivated for 10 weeks in hydroponic system. The plants were grown under controlled conditions of cultivation chamber (25/23°C, 16 h photoperiod, 250 µmol photons · m^{-2} · s^{-1} PAR).

Experimental treatments:

- Control (½ Hoagland solution)
- Control + Priming (seeds primed in PAW and grown in ½ Hoagland solution)
- PAW (PAW supplemented with ½ Hoagland solution)
- PAW + Priming (seeds primed in PAW and grown in PAW supplemented with ½ Hoagland solution)

For priming, seeds were immersed in PAW for 1.5 hours. The pH of the solutions was adjusted to 6.2. Solutions was changed every 7 days.

Preparation of PAW

PAW was prepared by treating 5 L of tap water (pH = 7.9) with 21 parallel transient spark (TS) discharges over 238 minutes. Each TS operated at ~1 kHz with electrodes 1 cm above the water surface. Freshly treated PAW + Hoagland s. had typical characteristics: H_2O_2 = 267 µM, NO_2^- = 1233 µM, and NO_3^- = 23146 µM.