Cultivation of hydroponic Lettuce in plasma-activated water: effects on growth, pigmentation, and sensory quality

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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

The main objective of this study was to evaluate the effects of **seed priming** with PAW and subsequent **hydroponic cultivation in PAW-enriched Hoagland solution on lettuce.** The study focused on plant growth, photosynthetic pigments, and the impact of these treatments on sensory attributes, including taste, visual appearance, and aroma, assessed through a sensory evaluation.

Conclusion

- Application of **PAW** alone led to:
  - the **lowest fresh weight** and **smallest leaf head size,**
  - **the highest levels** of **chlorophyll *a*** and **phenolic compounds**, correlating with its perception as the **greenest** variant in sensory evaluation.
  - the **lowest concentration** of **pheophytin *a*** and **carotenoids.**
- Application of **PAW + priming** significantly:
  - **improved biomass** and **leaf head size**, resulting in the **largest and most palatable** plants,
  - Increased **chlorophyll *a+b*** and **pheophytin *a+b*** **concentrations** to the highest level.

Acknowledgement

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References

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RECOVERY AND RESILIENCE PLAN

Results

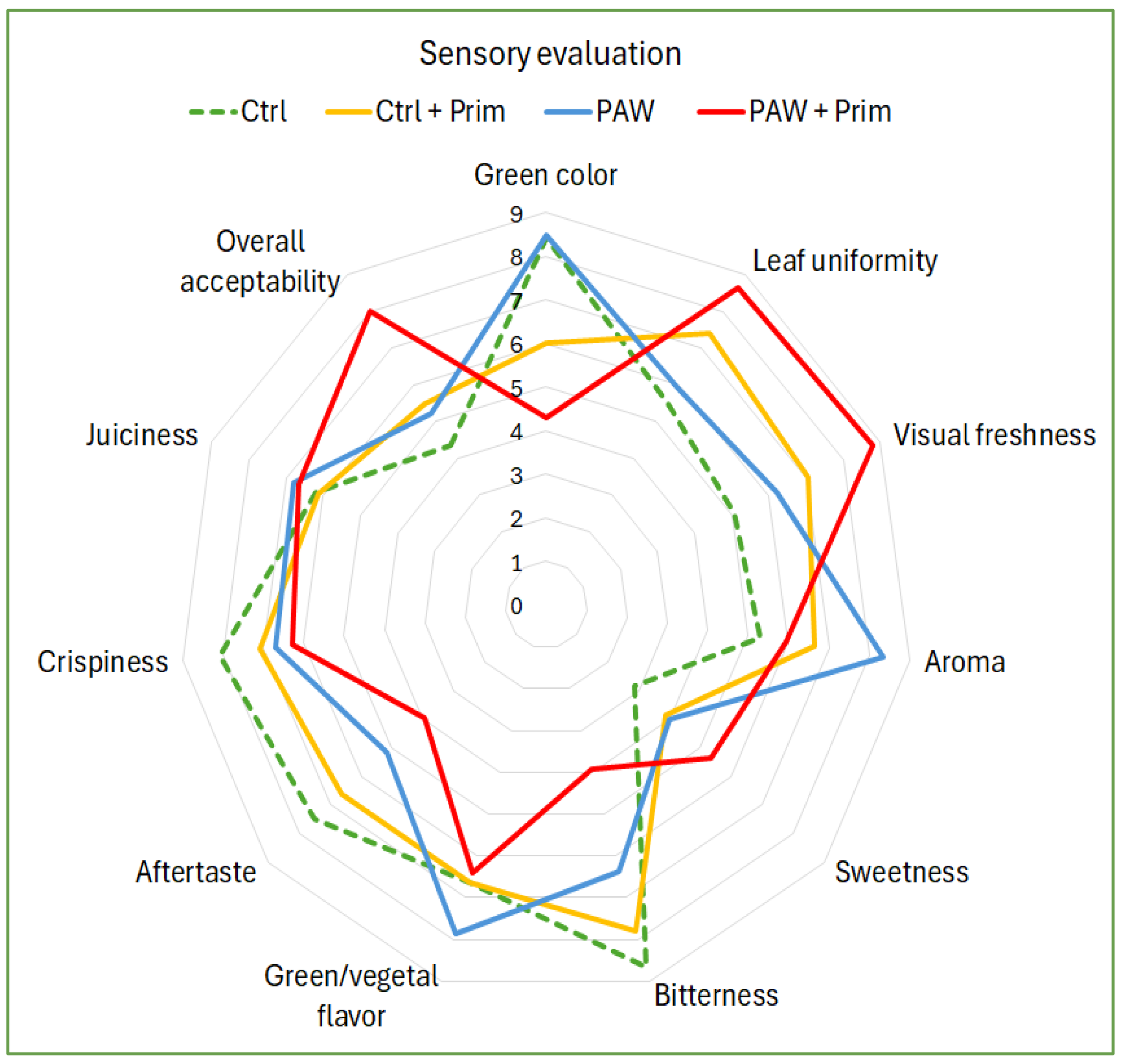

Figure 1: Sensory testing of lettuce after 10 weeks of cultivation.

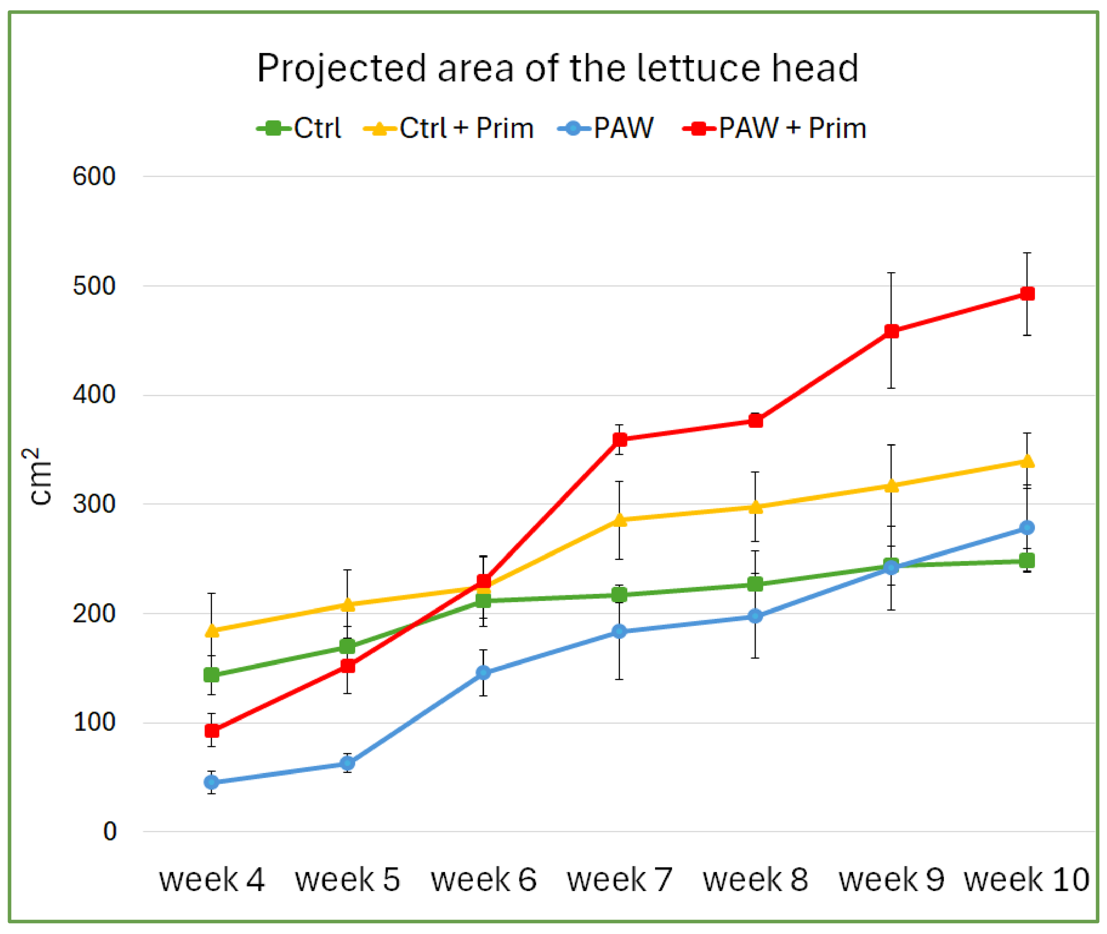

Figure 2: Projected area of the lettuce head from the 10-week cultivation.

Factor	Leaf area
treatment (A)	***
week (B)	***
interaction A x B	***

LSD test for factor treatment	Homogenous groups
PAW	a
Ctrl	b
Ctrl + Prim	c
PAW + Prim	d

LSD test for factor week	Homogenous groups
week 4	a
week 5	b
week 6	c
week 7	d
week 8	e
week 9	f
week 10	g

Table 1: Two-way ANOVA of the projected area of the lettuce head from the 10-week cultivation. Different letters indicate statistically significant differences among treatments or weeks according to LSD test (P≤0.05).

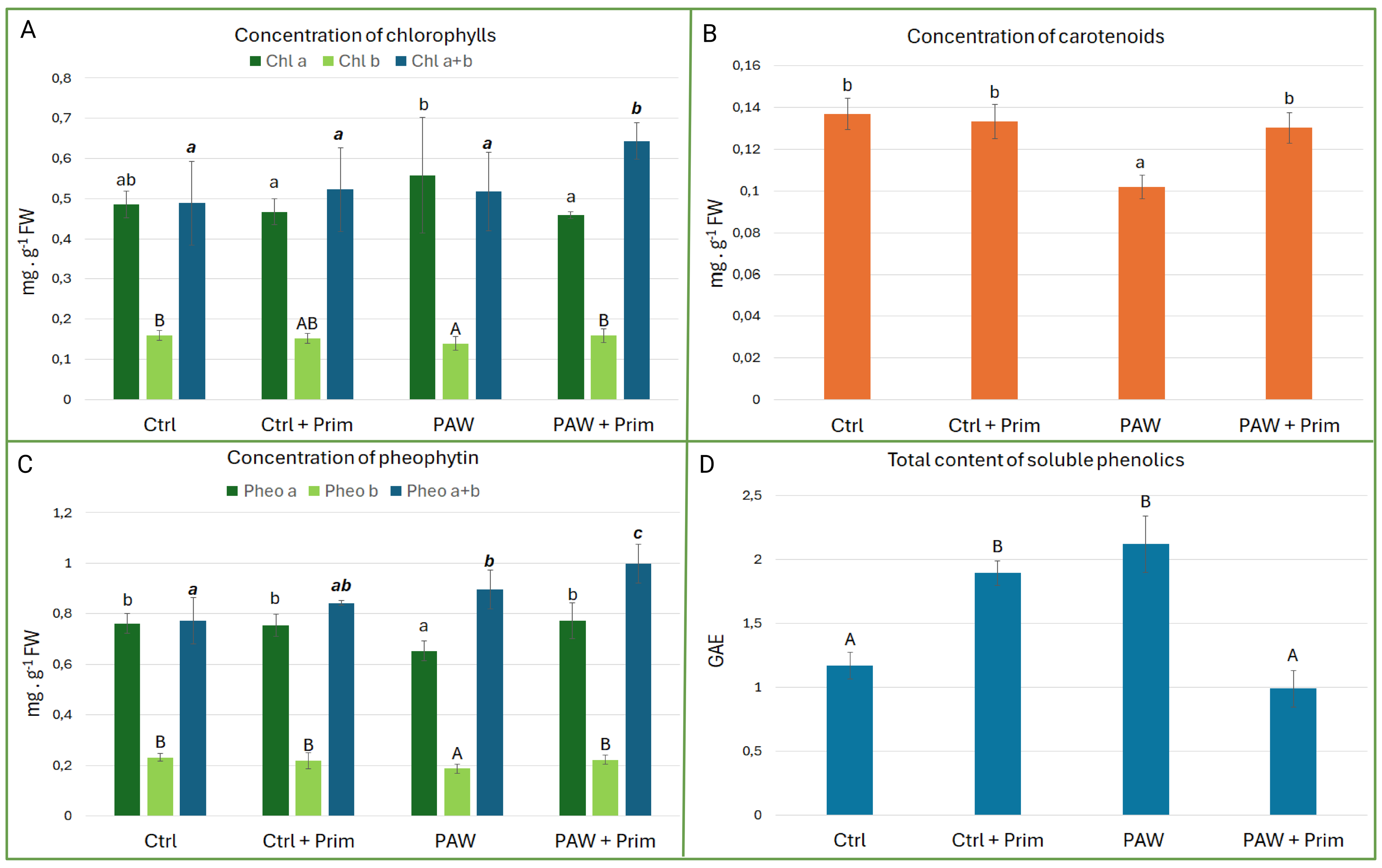

Figure 3: Concentrations of chlorophylls (A), carotenoids (B), and pheophytins (C) in mg·g⁻¹ fresh weight (FW) in lettuce. Total content of soluble phenolics (D) is also presented. Different letters indicate statistically significant differences among treatments according to LSD test (P≤0.05).

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.

Determination of the lettuce head

At the two-rosette stage (week 4), plants were photographed weekly and analyzed in ImageJ.

Concentration of chlorophylls and carotenoids

Concentration was determined spectrophotometrically according to Lichtenthaler.

Total soluble phenolics content

Total content was determined spectrophotometrically according to Ainsworth and Gillespie.

Sensory testing

After 10 weeks, 15 respondents (age 23–71) evaluated taste, visual appearance, and aroma.

Statistical analysis

Statistical analysis was performed using Statgraphics Centurion and Microsoft Excel. Differences among individual treatments were evaluated based on statistical analyses (multifactor ANOVA, LSD test) at a significance level of P ≤ 0.05.

Preparation of PAW

5 L tap water (pH 7.9) was treated with 17 parallel transient spark discharges (~1 kHz, electrodes 1 cm above surface) for 238 min. Fresh PAW + Hoagland solution contained H_2O_2 = 267 μM, NO_2^- = 1233 μM, NO_3^- = 23146 μM.