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Cutting-edge research into induction of plant responses by irradiation of atmospheric pressure plasma

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Non-thermal atmospheric-pressure air plasma technologies have recently emerged as promising tools to enhance environmental resilience and sustainability in agriculture [1]. Using a dielectric barrier discharge (DBD) plasma device, we have demonstrated that brief plasma irradiation (1–5 minutes) on seeds significantly improves germination, growth, and stress tolerance in various species, including *Arabidopsis thaliana*, rice (*Oryza sativa* cv. Nipponbare), radish (*Raphanus sativus* L.), and lettuce (*Lactuca sativa* L.) [2–10]. This chemical-free method is simple, rapid, and compatible with organic farming, offering a sustainable alternative to agrochemicals. Plasma exposure triggers a cascade of molecular and physiological responses in plants. At the hormonal level, it reduces abscisic acid (ABA) and increases gibberellin (GA), promoting germination [8,9]. In leaves, plasma sustains elevated GA and enhances expression of photosynthesis-related proteins. Transcriptome analysis shows downregulation of ABA biosynthetic genes and upregulation of ABA catabolic and α-amylase genes, facilitating dormancy release and germination. Epigenetically, plasma induces DNA methylation changes: hypermethylation in the NCED5 promoter and hypomethylation in Amy1C and Amy3E promoters correlate with altered gene expression [11], suggesting a novel regulatory layer contributing to plasma-induced phenotypes. Moreover, mass spectrometry confirms that plasma introduces quantifiable nitrate ions (NO_3^-) into seeds [12], which act through NLP8 binding to the CYP707A2 promoter, regulating ABA metabolism, gene expression, and signal transduction. Plasma also alters other hormone balances and antioxidant levels, enhancing plant resilience to drought and salinity. Importantly, feeding studies confirm the safety of rice grown from plasma-treated seeds, with no subacute toxicity observed in mammals [3]. Because seed responses vary by physiological condition, treatment optimization is essential [10]. Recently, new methods have been developed to assess immediate post-exposure responses in plants such as Marchantia polymorpha [13,14], bridging the time gap between plasma exposure and omics changes. Integrating physics, plant biology, and sustainability, plasma agriculture offers powerful tools for building resilient food systems under climate change. This talk will present the latest insights into plasma–seed interactions and their implications for sustainable agriculture.

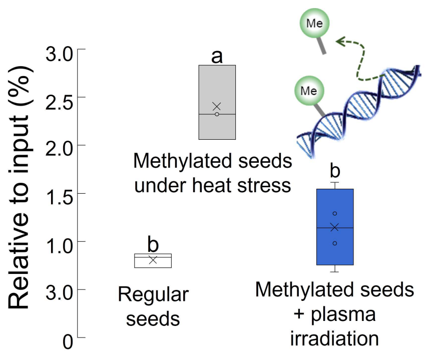

Fig. 1. Modification of methylation levels of seeds under dry conditions, induced by plasma irradiation.

References

[1] P. Attri et al., Processes, 8(8), 1002 (2020).
[2] S. Kitazaki et al., Current Applied Physics, 14 (2014).
[3] T. Okumura et al., Scientific Reports, 13, 17450 (2023).
[4] H. Hashizume et al., Plasma Processes and Polymers, 18(1), 2000181 (2021).
[5] L. Degutytė-Fomins et al., Japanese Journal of Applied Physics, 59, SH1001 (2020).
[6] K. Koga et al., Applied Physics Express, 9 (2015).
[7] K. Kazunori et al., Japanese Journal of Applied Physics, 59, SHHF01 (2020).
[8] P. Attri et al., Scientific Reports, 11, 2539 (2021).
[9] V. Mildaziene et al., Scientific Reports, 9 (2019).
[10] T. Okumura et al., Applied Physics Express, 17, 057001 (2024).
[11] C. Suriyasak et al., ACS Agricultural Science & Technology, 1(1), (2021).
[12] T. Okumura et al., Scientific Reports, 12, 12525 (2022).

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