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Applied potential of cold plasmas for seed processing

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In the context of rapid population growth, climate change, and resource constraints, sustainable and smart agriculture has become essential. Obtaining high yields in agricultural production starts with planting seeds that germinate in high percentages and produce robust plants with minimal delay. The potential of seed irradiation with low temperature plasmas (cold plasmas, CP) for application in agriculture is under intensive investigation, as a green alternative to conventional chemicals (fertilizers, pesticides and herbicides). It has been demonstrated on numerous crop species that short term seed irradiation with low-pressure or atmospheric CP devices can decrease microbial seed contamination, improve yields and increase robustness of plants through complex wide-scale changes evolving at the epigenomic, transcriptomic, proteomic and metabolic levels. In the last decade, many important aspects at the molecular level have been revealed, and the knowledge of such mechanisms has an immense potential for applications in agriculture.

The accumulated body of evidence indicates to the high complexity of seed response to CP treatment on the molecular level. Increased amount of photosynthetic pigments and upregulated photosynthesis, improved root development results in enhanced growth, while the stimulated secondary metabolism leads to better plant establishment, fitness and stress resistance. The most important novel findings on such response induced in dry seeds are changes in EPR signal, DNA methylation, balance of phytohormones, expression of genes and proteins, enzyme activities, modified seed microbiome. CP-induced changes in reactive oxygen species production were reported in the germinating seeds. The events of seed response to the CP stress signal are further developed in the growing plant. This is manifested as multiple interrelated changes in gene expression due to DNA methylation, changes in protein expression, activities of numerous enzymes important for photosynthetic system, secondary metabolism and antioxidant defense. Modulation of secondary metabolism and capacity of the antioxidant system is associated with an increased plant fitness and resistance to biotic and abiotic stress, as well as modified plant communication with microorganisms - both pathogens and plant growth promoting microorganisms, e.g. N-fixating rhizobacteria. Thus, seed treatments with CP induce mobilization of the molecular mechanisms leading to improved chances for plant survival, including better establishment, stress resistance and productivity.

Understanding the complex interactions between seeds and CP remains challenging due to the intricacy of seed structure and yet unidentified molecular systems involved in signal perception and transduction. Further, reproducing observed effects poses reliability concerns for these technologies. A better grasp of the dependence on factors such as species, cultivar, genetic lineage, plant gender, and seed polymorphism could enhance reproducibility and reliability. Furthermore, the development of strategies for the technology transfer from the laboratory practice for medium and large scale application in cooperation with the industry is required.

Speaker's Affiliation

Vytautas Magnus University, Kaunas

Member State or IGO/NGO

Lithuania

Primary author: MILDAŽIENĖ, Vida (Vytautas Magnus university)

Presenter: MILDAŽIENĖ, Vida (Vytautas Magnus university)

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