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Nonthermal plasma as a novel seed treatment technology for imparting climate change adaptability to plants

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The global environment is balanced among many factors on the earth. However, the balance is changed by the human activities. To evaluate the balance change, the Planetary Boundary has been proposed, and pointed out that the nitrogen cycle, climate change, and biodiversity loss are significantly unstable [1]. The nitrogen cycle refers to the transformation of nitrogen gas into ammonia and nitric acid and finally back into nitrogen gas [2]. Currently, the nitrogen cycle has broken down. One major reason is excessive administration nitrogen fertilizers. It induces the increase of the concentrations in soil and groundwater and makes pressure of environmental change. Harvest yield of crops is going to decrease due to the environmental change. In the case of rice, the harvest is predicted 10-15% decrease in 2050 compared to 2014. Declining yields will drive increased fertilizer consumption. In addition, the Haber-Bosch process, which is essential for fertilizer production, emits CO_2. Nitrogen fertilizer consumption emitted 700 million tons of CO_2 in 2014, making it a major source of CO_2 emissions, accounting for 1-2% of global CO_2 emissions. CO_2 emissions associated with increased fertilizer consumption, which will increase due to environmental change, are expected to increase by 23% by 2050.

Effects of plasma irradiation on plants have attracted much attention and examined many aspects of agricultural activity [3]. For example, plasma-irradiated seeds enhance germination and overall growth [4-12].

When parental plants are exposed in temperatures of 30°C or higher during the rice-planting stage, harvested seeds exhibit high-temperature stress that results in degraded germination characteristics and rice quality. This is an example of the adaptation of plants against heat, leading to degradation of food productivity. The plasma irradiation to seeds is expected to alter the inherent environmental adaptability of plant seeds in a posteriori manner. We have demonstrated that plasma irradiation of heat stressed seeds improves germination characteristics [13]. The plasma-irradiated seeds show better germination characteristics and change the gene expression related abscisic acid (ABA) and α-amylase [13]. Further, the plasma irradiation to seeds alters methylation in DNA promotors of ABA and α-amylase. These results show that plasma irradiation to seeds allows us to regulate epigenetics, altering DNA methylation. It suggests that plasma is promising to change plants with environmental adaptability. This method helps to recover from the decline in food productivity caused by global warming and reduces fertilizer consumption.

To reveal the effects of plasma, it is important to evaluate the amount of plasma-induced particles (Reactive oxygen and nitrogen species, photons, ions, etc.) supplied into the seeds to understand the effects of plasma at the molecular level. We examined mass spectrometry of plasma-irradiated seeds. We found that nitrate ion, NO_3^-, is introduced in seeds as RONS upon irradiation with plasma [14]. NO_3^- in plant seeds is responsible for inducing responses such as dormancy break, gene expression regulation, signal transduction, and ABA metabolism resulting from NLP8 binding to the CYP707A2 promoter.

In this presentation, we will show the recent results regarding plasma irradiation to seeds.

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