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Impact of Atmospheric Pressure Plasma Irradiation to Seeds on Agricultural Productivity

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Improvement of agricultural productivity using environmentally friendly methods is an important issue for the sustainable development of the world. Introducing reactive species to plants was attracted great attention to realize the productivity improvement by regulating eustress response in plants. Non-thermal plasma is a promising method to promote the eustress response because it can generate a high density of reactive oxygen species (ROSs) and reactive nitrogen species (RNSs) due to energetic electron collisions to gas molecules without thermal damage to plants. We have compared the effects of plasma irradiation to seeds on the plant activity with that of the gamma-ray irradiation to seeds. ROS dose has been measured using KI-starch method [1]. The method has been employed for 3-D visualization of dose distribution of radioactive rays which induce ROS generation [2]. We measured ROS generation in KI-starch solution irradiated by the plasma generated using a scalable dielectric barrier discharge (SDBD) device [3] and the gamma-ray emitted from Co60. The seeds of radish sprouts are irradiated by the two methods under the same dose. Figure 1 shows a comparison between plasmas and gamma-ray. The gamma-ray irradiation above 10 Gy shows cell death, while the cell death is occurred by the plasma irradiation longer than 200 s. The ROS dose for 10 Gy in the gamma-ray dose is 0.03 times smaller than that for 200 s in plasma irradiation time. It indicates that the plasma irradiation offers a significantly higher dose of ROS to seeds with no damage. On the other hand, the lifetime of the reactive species generated by plasmas is significantly short compared with chemicals such as fertilizer. Thus the plasma can realize the irradiation to plants with little damage to the crop field.

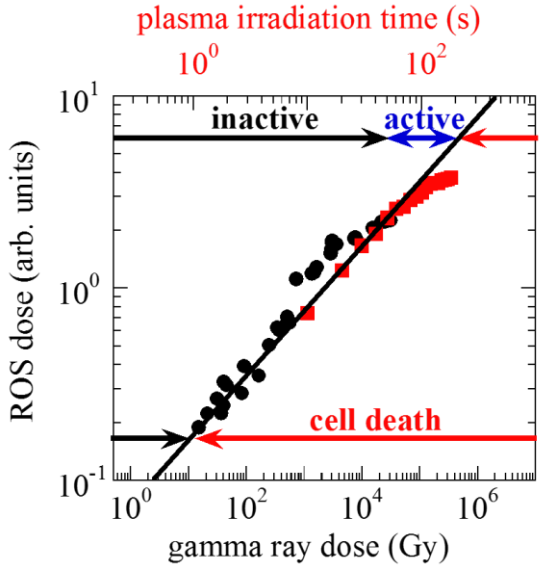

Fig. 1. Comparison between ROS dose by plasma irradiation and gamma-ray irradiation.

We have examined the plasma irradiation to seeds of 12 kinds of plants. For example, Arabidopsis thaliana seeds, plasma irradiation reduces 11% in a first harvest period from sowing and increases 56% in total crop amount [4]. For seeds of sorghum which is a strong candidate of biomass plants to produce ethanol [5, 6], the irradiation shows 74 % increase of the estimated volume of the plant. Under the same irradiation conditions, we confirmed 8 kinds of plants shows the growth enhancement [4, 7]. That shows the sensitivity against plasma depends on the plants.

We estimated the energy consumption of the plasma irradiation to seeds of sorghum is 4.7MJ/ha while that for the general farm work is estimated to be 3.3 GJ/ha. On the other hand, the estimated energy leverage by plasma irradiation is $1x10^4$. These show the plasma is an innovative and environmentally friendly method to improve agricultural productivity.

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