Mechanism of Plant Growth Enhancement by Water Vapour and Hydrogen Plasmas Irradiation

Ziyu Shi[1], Koji Matsumoto[1], Nobuya Hayashi[1]

[1] *Interdisciplinary Graduate School of Engineering Sciences, Kyushu university, 6-1 Kasuga-kouen, Kasuga-shi, Fukuoka 816-8580, Japan*

Abstract: The effect of reducing active species in low-pressure water vapour and hydrogen plasmas on plant growth is investigated. The active oxygen species OH* generated by water vapour plasma activated oxidant stress in the plant cells to activate the production of antioxidant substances. Reducing active species H* to optimize the redox balance in plant cells with hydrogen plasma irradiation. And by the gene expression analysis, the growth enhancement would be attributed to the variation of gene expression of expansin.

Keywords: water vapour plasma, hydrogen plasma, plant growth enhancement.

1. Introduction

Plant growth enhancement has been observed when plant seeds are irradiated with plasmas. Active species in the plasmas are considered to be stimuli to plants, and induce growth enhancement and antioxidant activity[1]. However the husk of seed may be damaged by energetic particles generated in plasmas. There is need to find a gas species that causes less damage to the husk of the seed. In this study, the effect of reducing active species in low-pressure water vapour and hydrogen plasmas on plant growth is investigated. Biological responses of plants treated with water vapour and hydrogen plasma is attempted to be elucidated by gene expression analysis.

2. Experimental apparatus and condition

A cylindrical vacuum chamber with an inner diameter of 210 mm and a length of 490 mm is used. The RF electrode powered with the frequency of 13.56 MHz is arranged along the inner wall of the vacuum chamber1). *Radish sprouts* and *Arabidopsis thaliana* seeds are used as sample. The plasma is generated by water vapour with the RF power and irradiation period of 50W and 20min, respectively. Hydrogen plasma is generated with the RF power and irradiation period 50W and 2min, respectively. Active species such as H and OH radicals are generated in water vapour and hydrogen plasmas. After irradiation, the *Radish sprout* seeds are hydroponically cultivated in the dark condition at 24°C. Then, the total length of *Radish Sprouts* is measured after 4 days of cultivation. *Arabidopsis thaliana* seeds are cultivated in soil under the LED lamp. The total length of *Arabidopsis thaliana* is measured after 2 months of cultivation. The mechanism of the plant growth enhancement is attempted to be determined, comparing the growth enhancement effect and changes in gene expression of *Arabidopsis thaliana*.

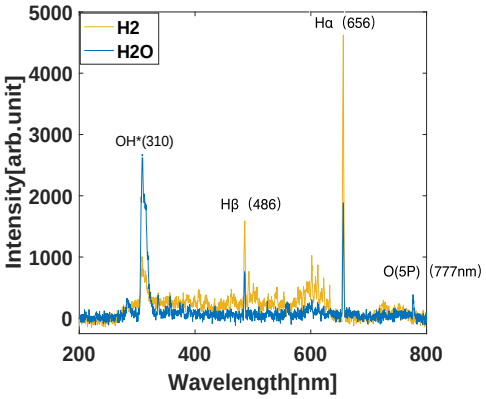

Fig.1. Light emission spectra of water vapour and hydrogen plasmas

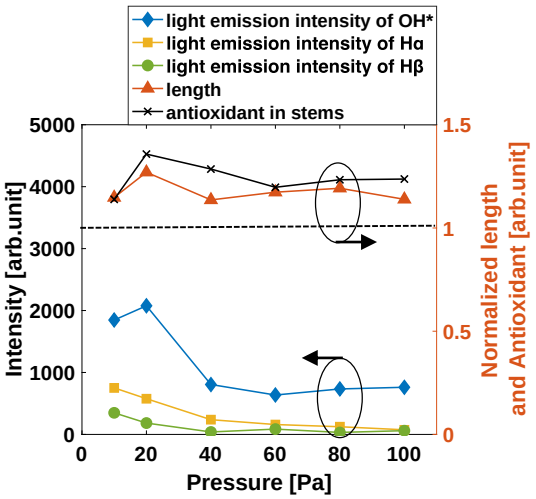

Fig.2. Dependences of length of radish sprouts, amount of antioxidant in stems and light emission intensities of Hα, Hβ and OH* on water vapour pressure

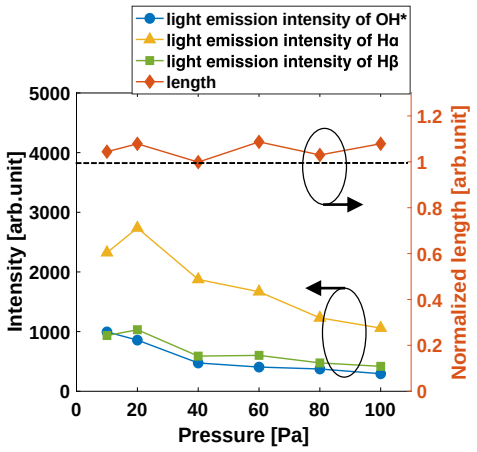

Fig.3. Dependence of length of radish sprouts and light emission intensities of Hα, Hβ and OH* on hydrogen pressure

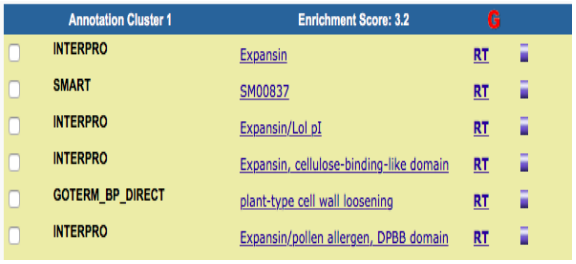

Fig.4. Functional annotation chant of biological function and process induced by hydrogen plasma irradiation with 20Pa and 100W

3. Results and discussion

Figure 1 shows light emission spectra of water vapour and hydrogen plasmas. The major species in water vapour and hydrogen plasmas are OH and H radicals.

Figure 2 shows water vapour plasma pressure dependence of the length of *Radish Sprouts* and antioxidant in stems and light emission intensity of H_α and H_β and OH*. Maximum growth rate is obtained at 20Pa. Maximum light intensity of OH* is also obtained at 20Pa. From this result, it is considered that there is a possibility that the active oxygen species OH* generated by water vapour r plasma activated oxidant stress in the plant cells to activate the production of antioxidant substances.

Figure 3 shows dependences of the length of *Radish Sprouts* and light emission intensities of H_α, H_β and OH* on hydrogen pressure. The growth rate tendency is similar with variation of light emission intensity of H*. From this result, reducing action of active species H* to optimize the redox balance in plant cells would be a factor for the growth promoting effect.

Figure 4 shows functional annotation chant of biological function and process induced by hydrogen plasma irradiation with 20Pa and 100W. Many genes with annotation of the biological function of "Expansin" were expressed. Expansin is a kind of proteins which involved in cell wall synthesis and metabolism. When seeds are irradiated with plasma, the hydrogen ions (H^+) increase extracellularly. Electrons are released from the cell wall to the outside of the cell. And then, the inside of the cell wall is deprived of electrons and acidified. Therefore, expansin enzyme induces sagging of the cell wall and elongation growth of plant tissue is induced with plant cells uptake water.

4. Summary

The generated active oxygen OH* is a cause of plant growth promotion when irradiated with a water vapour plasma. Also the reducing active substance H* is a plant growth enhancement factor. Owing to gene expression analysis, the growth enhancement of *Arabidopsis thaliana* induced by hydrogen plasmas would be attributed to the variation of gene expression of expansin.

5. References

[1] R. Ono and N. Hayashi, Japanese Journal of Applied Physics, **54**, 06GD03 (2015).