9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Nitrogen gas fertilization via plasma technology to promote plant growth

Taro Yamanashi[1], Yuto Sato[1], Md. Firose Hossain[1], Takeshi Uchiyama[1], Shota Sasaki[2], Toshiro Kaneko[2], Kazunori Koga[3], Masaru Tsuji[1], Yasuhiro Ishimaru[1] and Nobuyuki Uozumi[1]

[1]Department of Biomolecular Engineering, Graduate School of Engineering, Tohoku University,
[2]Department of Electronic Engineering, Graduate School of Engineering, Tohoku University,
[3]Graduate School of Information Science and Electrical Engineering, Kyushu University
uozumi@tohoku.ac.jp:

Nitrogen is one of the essential macronutrients for plants, and the nitrogen content in soil is directly linked to crop productivity. To meet the growing global demand for food due to population increase, it is crucial to supply nitrogen in a form that plants can utilize as fertilizer. The development of the Haber-Bosch process led to a dramatic increase in nitrogen fertilizer production. However, the Haber-Bosch process consumes a large amount of energy. Additionally, nitrogen fertilizers (NH_4^+, NO_3^-) can leach into the environment, and excessive fertilization leads to residual nitrogen, causing soil and environmental pollution. Therefore, environmentally friendly and appropriate nitrogen supply methods are increasingly desired for building a sustainable society.

In this context, plasma-based nitrogen supply has emerged as one promising alternative. Plasma-based nitrogen fixation can be operated at room temperature and atmospheric pressure, allowing for reduced energy consumption and high compatibility with renewable energy sources. The equipment can also be easily miniaturized, enabling on-site, on-demand adjustment and immediate fertilizer supply.

Solid and liquid fertilizers are the standard methods for nitrogen supply. On the other hand, nitrogen compounds generated using plasma devices, can be supplied to plants as a new form of "gaseous nitrogen fertilizer." We are investigating the potential use of plasma irradiation for nitrogen fertilizer applications.

Atmospheric pressure plasma devices can convert inert atmospheric nitrogen into gaseous nitrogen compounds. These nitrogen compounds react with water to form nitrate, making them potentially usable as nitrogen sources for plants. To explore this possibility, we used the model plant *Arabidopsis thaliana* and examined the optimal conditions for plasma irradiation. When plasma-generated gas was introduced into nitrogen-free liquid culture medium and supplied to nitrogen-deficient plants, plasma-gas application alleviated nitrogen deficiency symptoms to a degree comparable to that of calcium nitrate treatment.

The application reduced anthocyanin accumulation over time, it also caused leaf damage. On the other hand, by improving the plasma irradiation method, we succeeded in restoring the growth of nitrogen-starved plants without inducing damage. Plasma-based production of plant-available nitrogen sources represents a promising approach for future agricultural applications.

References

[1] Sasaki et al. Ind Eng Chem Res60:798-801. (2021)
[2] Yamanashi *et al.* Plant Mol. Biol. 114:35, (2024)

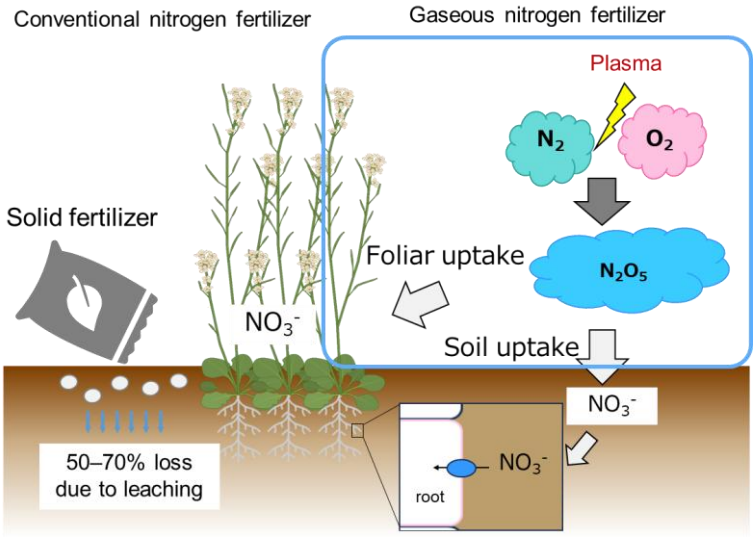

Figure 1. Plasma-generated gaseous nitrogen fertilizer